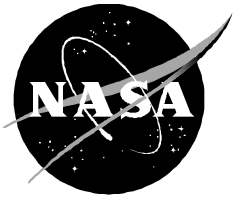

National Aeronautics and
Space Administration

Evaluation and Enhancement of Decision Support Tools – FY2003 Report

Earth Science Applications Directorate
John C. Stennis Space Center, Mississippi

National Aeronautics and
Space Administration

John C. Stennis Space Center
SSC, Mississippi 39529

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Executive Summary

During the fiscal year 2003 (FY2003), the Earth Science Applications (ESA) Directorate at the NASA John C. Stennis Space Center (SSC) in Mississippi provided systems engineering support for the National Applications program of the NASA's Earth Science Enterprise (ESE). The purpose of the National Applications program is to enable the results from NASA's Earth science research activities to serve decision support tools implemented by partner agencies and organizations. The Applications Division of the Earth Science Enterprise has defined 12 National Applications:

Agricultural Efficiency	Coastal Management	Homeland Security
Air Quality	Disaster Management	Invasive Species
Aviation	Ecological Forecasting	Public Health
Carbon Management	Energy Management	Water Management

Through systems engineering, ESA systematically assimilates results of ESE missions, models, and technologies into decision support systems (DSSs) that affect policies and societal impacts. The main DSSs identified for enhancement by assimilation of the ESE results are:

- *Agricultural Efficiency*: Crop Condition Data Retrieval and Evaluation (CADRE) from the U.S. Department of Agriculture - Foreign Agricultural Service - Production Estimates and Crop Assessment Division (PECAD)
- *Air Quality*: Community Multi-Scale Air Quality Modeling System (CMAQ) and Air Quality Index Forecasting from the Environmental Protection Agency (EPA)
- *Aviation*: Aviation Weather Information Network (AWIN) and Synthetic Vision System (SVS) components of the National Airspace System (NAS) from the Federal Aviation Administration (FAA)
- *Carbon Management*: tools developed to implement Section 1605(b) of Energy Act of 1992: Voluntary Sequestration of Greenhouse Gases from the U.S. Department of Energy
- *Coastal Management*: Harmful Algal Bloom (HAB) Mapping System (HABMapS) and HAB Bulletin from the U.S. Department of Commerce - National Oceanic and Atmospheric Administration (NOAA)
- *Disaster Management*: Hazards U.S. (HAZUS) from the Federal Emergency Management Agency (FEMA)
- *Energy Management*: RETScreen renewable energy project analysis software from the Natural Resources Canada (NRCan)
- *Invasive Species*: Invasive Species Forecasting System (ISFS) from the U.S. Department of Agriculture and the U.S. Geological Survey (USGS)

- *Public Health*: Environmental Public Health Tracking Network (EPHTN), Arbovirus Surveillance Network (Arbonet), and Malaria Modeling and Surveillance (MMS) from the Center for Disease Control and Prevention (CDC)
- *Water Management*: RiverWare river basin modeling software and Agricultural Water Resources and Decision Support (AWARDS) from the U.S. Department of the Interior - Bureau of Reclamation, and Better Assessment Science Integrating Point and Nonpoint Source (BASINS) from the EPA

The FY2003 systems engineering approach consisted of evaluation, verification & validation, and benchmarking of the DSSs. The intent of the evaluation process in FY2003 was largely to increase SSC/ESA's understanding of several DSSs in anticipation of partner meetings and detailed requirements studies. Verification and validation (V&V) is undertaken to ensure quality of the enhanced DSS. DSS results are verified by comparison to technical specifications using *in situ* measurements and cross-comparisons with other DSSs, models, and data sources. Interactions with the DSS end users allow SSC/ESA to validate whether the outcome of the enhanced DSS meets the functional desires of the DSS owner. In general, V&V conducted in support of the National Applications occurs on three levels: Data Product V&V, Model and Algorithm V&V, and DSS V&V. Benchmarking of a DSS is a process of measuring the performance of the DSS according to specified standards and reference points to document its value and to identify areas for improvements.

Ten lessons learned were identified during the FY2003 DSS evaluations:

- Successful use of NASA observations and predictions within DSSs often evolves from existing science research performed in collaboration with agency partners.
- The greatest opportunities for integrating NASA data into DSSs are often found with DSSs that are in early development stages.
- Many of the currently identified DSSs do not fit the Applications Program definition of DSS (Appendix A).
- It is often difficult to gain access to the appropriate persons to understand DSS operation and technical requirements.
- Synergy exists between many DSSs and applications.
- The process to bring R&D technology and products to operational use requires significant investments of time and funds.
- DSS technical requirements and specifications are difficult to identify.
- NASA scientists in residence at operational agencies (or other agency scientists resident at a NASA center) can foster the incorporation of NASA inputs into operational environments.
- DSS owners and DSS users are not always the same entity. Frequently the user/analyst involvement will impact the DSS's operation in ways the owner/developer will not have anticipated.

- NASA ESE Applications Program definitions for key terms, such as systems engineering, evaluation, assimilation, and benchmarking, are not always consistent with commonly accepted use of these terms.

Several key technology drivers and gaps affecting NASA's ability to meet the DSS enhancement needs were also identified during the evaluation process:

- Redundancy of systems providing NASA observations
- Continuity of NASA systems and data products
- Size and format of the remote sensing dataset
- Availability of observations in the thermal IR spectral range
- Incorporation of application-oriented system specifications
- Availability of particular product timescales

Based on the FY2003 experiences and the lessons learned, a modified ESA systems-engineering approach is proposed to make it more effective in future activities. The proposed modifications include (1) a better integration of the DSS selection process with the other processes that lead to assimilation of NASA observations and predictions into the enhanced DSS, and (2) a thorough investigation of alternative NASA inputs to the DSS by building NASA prototypes of the DSS enhancements.

1.0 Introduction

In April 2002, the National Aeronautics and Space Administration (NASA) redefined its mission as follows:

> *To understand and protect our home planet*
>
> *To explore the universe and search for life*
>
> *To inspire the next generation of explorers*
>
> *…as only NASA can.*

Earth system science is the first element of the NASA mission and it includes understanding the Earth's system and its response to natural and human-induced changes, investing in technologies, and collaborating with others to improve the quality of life and to create a more secure world. Thus, the mission of NASA's Earth Science Enterprise (ESE) is:

> *To develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.*

This mission is intended to increase our knowledge of the Earth as a system of interactive processes. To accomplish this mission, the ESE has established a science goal to "observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth" (NASA, 2001). ESE missions and research seek to answer questions related to the Earth's variability, the forces acting on it, the Earth's response, the resulting consequences, and improved predictions.

An important aspect of the Earth Science Enterprise is to ensure that results of ESE research and technology produce positive impacts for the citizens of the world. Consistent with the ESE mission, the Earth Science Enterprise Applications Program mission is as follows:

> *Expand and accelerate the realization of societal and economic benefits from Earth science, information, and technology.*

The ESE Applications Program contributes to the NASA vision by enabling individuals and organizations in the public and private sectors to routinely deliver and use Earth science information that saves lives, that improves the quality of life, and that saves resources through improved decision making. The success of the ESE Applications Program is based on the degree to which it has evaluated, verified and validated, and benchmarked the capacity of ESE results to serve national applications through improved decision-support solutions.

The Applications Division of NASA's Earth Science Enterprise has defined 12 National Applications that are the highest priority national needs and opportunities (NASA, 2002a, 2002b). The Applications Division at NASA Headquarters (HQ) has also identified decision support systems (DSSs) and decision support tools (DSTs) for the National Applications. The goal of the program is to enhance the National Application DSSs with NASA observations from remote sensing

systems and predictions from computational models. While the list of the selected DSSs is subject to change, this report includes those identified as of September 2003, as shown in Table 1.

Table 1. Decision support systems and tools as identified by ESA[1].

	National Application	Existing Decision Support Tools / Systems
	Agricultural Efficiency	Production Estimates and Crop Assessment Division (PECAD)
	Air Quality	Community Multiscale Air Quality modeling system (CMAQ)
		Air Quality Index
	Aviation	National Airspace System (NAS)
		Aviation Weather Information Network (AWIN)
		Synthetic Vision System (SVS)
	Carbon Management	Tools developed to implement Section 1605(B) of Energy Act of 1992 (EA92): voluntary sequestration of greenhouse gases
	Coastal Management	Harmful Algal Bloom Mapping System/Bulletin (HABMapS/Bulletin)
	Disaster Management	HAZUS Risk Prediction

[1] In September 2003, NASA HQ decided to suspend the Community Growth application because of the time required for development of national partnerships and decision support systems associated with this application. Ecological Forecasting was included as a new application because this area provides opportunities to apply Earth science measurements and predictions to decision support tools focused on ecological resources and management of ecosystems.

	National Application	Existing Decision Support Tools / Systems
	Ecological Forecasting	Regional Visualization and Monitoring System (SERVIR)
	Energy Management	RETScreen
		Natural Resources Canada (NRCan)
	Homeland Security	None identified
	Invasive Species	Invasive Species Forecasting System (ISFS)
	Public Health	Environmental Public Health Tracking Network (EPHTN) / Health and Environment Linked for Information Exchange (HELIX)
		Arbovirus Surveillance Network (Arbonet) / Plague
		Malaria Modeling and Surveillance (MMS)
		Rapid Syndrome Validation Project (RSVP)
	Water Management	RiverWare
		Better Assessment Science Integrating Point and Nonpoint Source (BASINS)
		Agricultural Water Resources and Decision Support (AWARDS)

The Earth Science Applications (ESA) Directorate at the NASA John C. Stennis Space Center (SSC) in Mississippi provides crosscutting systems engineering support for the National Applications. The mission of ESA is

> *To optimize benefits from NASA's Earth science investments through systems engineering to advance decision support tools that serve the nation.*

Through systems engineering, ESA systematically assimilates results of ESE missions, models, and technologies into DSSs and DSTs that affect policies and societal impacts. The Applications Division framework for accomplishing its mission and the role of SSC/ESA are depicted in Figure 1.

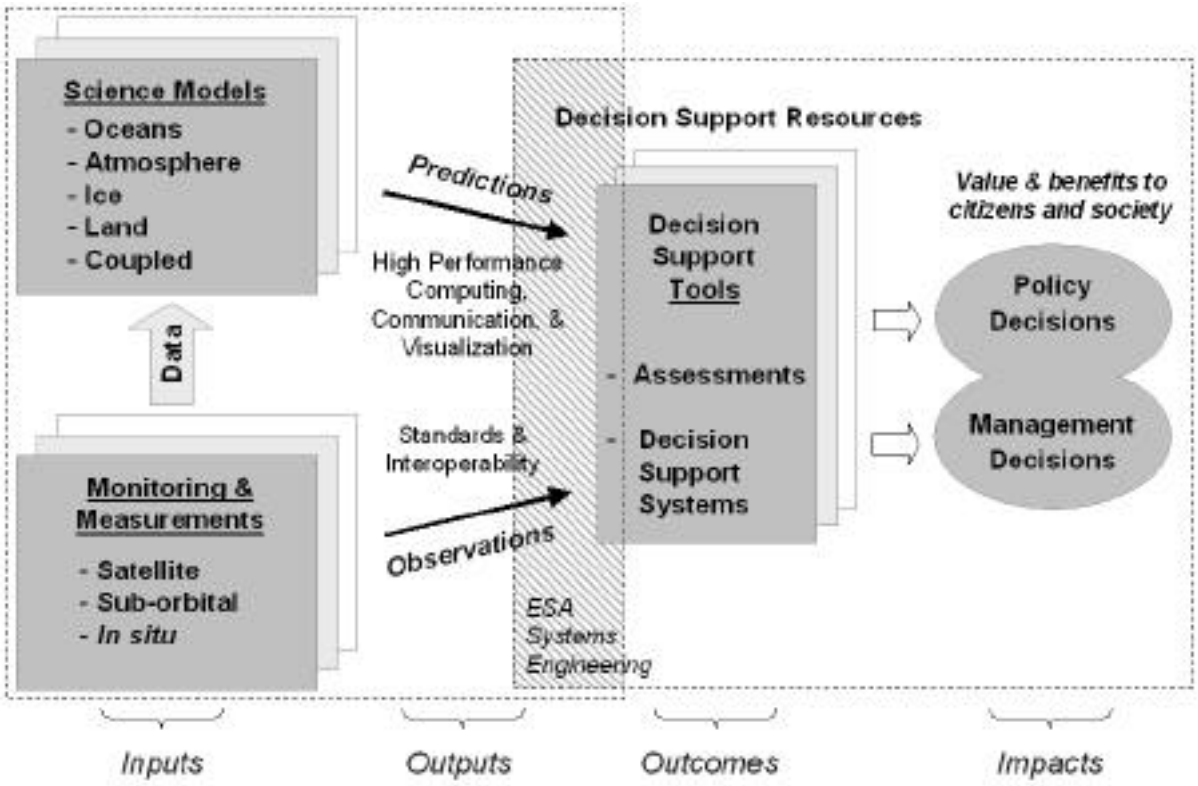


Figure 1. Applications framework and the role of ESA Systems Engineering.

This document describes the work conducted by SSC/ESA in FY2003 in beginning the evaluation of several DSSs and the lessons learned from these activities. This document also proposes improved processes for selection, evaluation, verification and validation, and benchmarking of DSSs.

2.0 FY2003 SSC Activities

As mentioned above, the evaluation, verification and validation, and benchmarking of ESE observations and model predictions within DSSs are critical components of the Applications Program. Definitions of the terms evaluation, verification, validation, and benchmarking are provided in Appendix A. In general, the evaluation phase involves understanding the requirements for and technical feasibility of Earth science and remote sensing tools and methods for addressing DSS needs. The verification and validation phase includes measuring the performance characteristics of data, information, technologies, and/or methods, and assessing the ability of these tools to meet the requirements of the DSS. In the benchmarking phase, the adoption of NASA inputs within an operational DSS and the resulting impacts and outcomes are documented.

The SSC Earth Science Applications Directorate is using a systems engineering approach for the assimilation of NASA data into the partner-agency DSSs. This standard systems engineering approach is summarized in Figure 2 along with its relationship to the evaluation, verification and validation (V&V), and benchmarking processes used in incorporating NASA contributions to decision support systems and tools. Use of systems engineering principles leads to scalable, systemic, and sustainable solutions and processes, which in turn contribute to the success of the mission, goals, and objectives of each National Application.

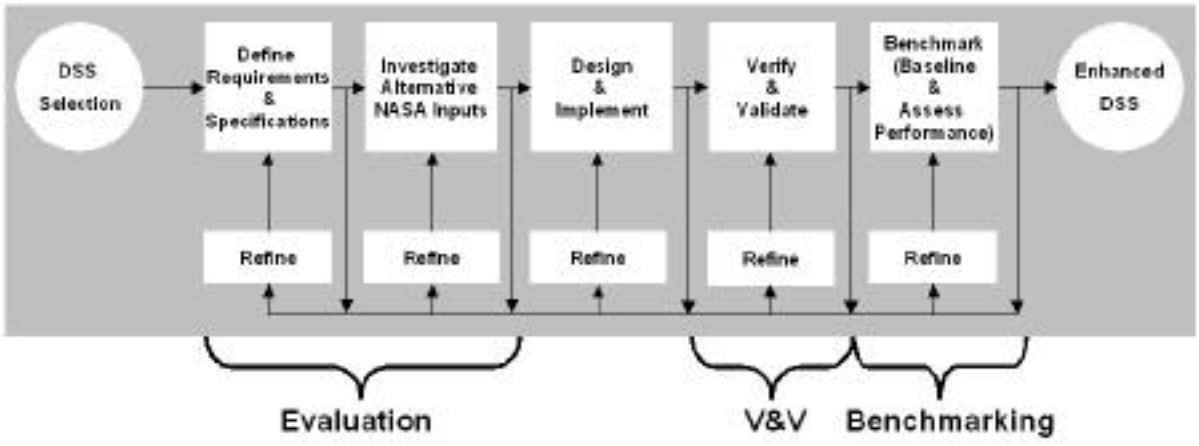


Figure 2. Systems engineering approach (adapted from Bahill and Gissing, 1998).

2.1 FY2003 Evaluation Approach

The systems engineering approach starts with the *Selection* of a DSS that has been developed, or is currently under development, by a federal agency that can potentially be enhanced by NASA observations or predictions. During the FY2003 activities, the DSS selection was made at NASA HQ, and the SSC work began with the *Evaluation* process (outlined in Figure 3). The intent of this process in FY2003 was largely to increase SSC's understanding of several DSSs in anticipation of partner meetings and detailed requirements studies. The evaluation process began with the development of a one-page summary giving a short description of the DSS function, the Federal agency owner, the national application involved, point of contact (POC) information, operational status, and a cursory look at potential use of NASA data. For the one-page summary, information was collected through searches of open literature and the Internet, and by individual phone and e-mail contacts with people familiar with the DSS. In addition to the DSSs identified by NASA HQ, one-page summaries were created for other decision support systems and tools with the potential to benefit from NASA inputs. In this manner, a decision-support system knowledge base was built for use by application program managers as a pool of potential opportunities for NASA. In total, more than 40 one-page DSS summaries were created with a possibility for enhancement with NASA data from remote sensing observations and computational modeling predictions. The one-page summaries are included as Appendix D of this report.

In the next step, a first-look evaluation was performed starting with information from the one-page summary. This first-look evaluation assessed relevance of the DSS to a national application and its synergy with other DSSs and national applications. Technical requirements for inputs and outputs of the DSS were also identified to allow for prediction of NASA contributions to the DSS. In addition, the first-look evaluation defined the next steps toward a possible NASA partnership with the DSS owner (e.g., Federal agency visit). Additional follow-up conversations with the DSS owner and people familiar with the DSS were conducted by phone when necessary. A strong knowledge of the existing ESE inventory of missions, sensors, products, and models is a valuable resource during the evaluation.

This ESE missions, sensors, products, and models inventory was developed to facilitate communications between NASA's Earth Science Enterprise Applications Division and its partners, specifically owners and operators of decision support systems. The material is directed at operational users (e.g., other agencies) rather than scientists, and it is intended to capture information relevant to these operational users. The inventory includes several hundred slides presenting top-level information on missions, sensors, data products, and models within NASA, other government agencies, foreign governments, and the commercial sector. The inventory slides are shown in the document accompanying this report.

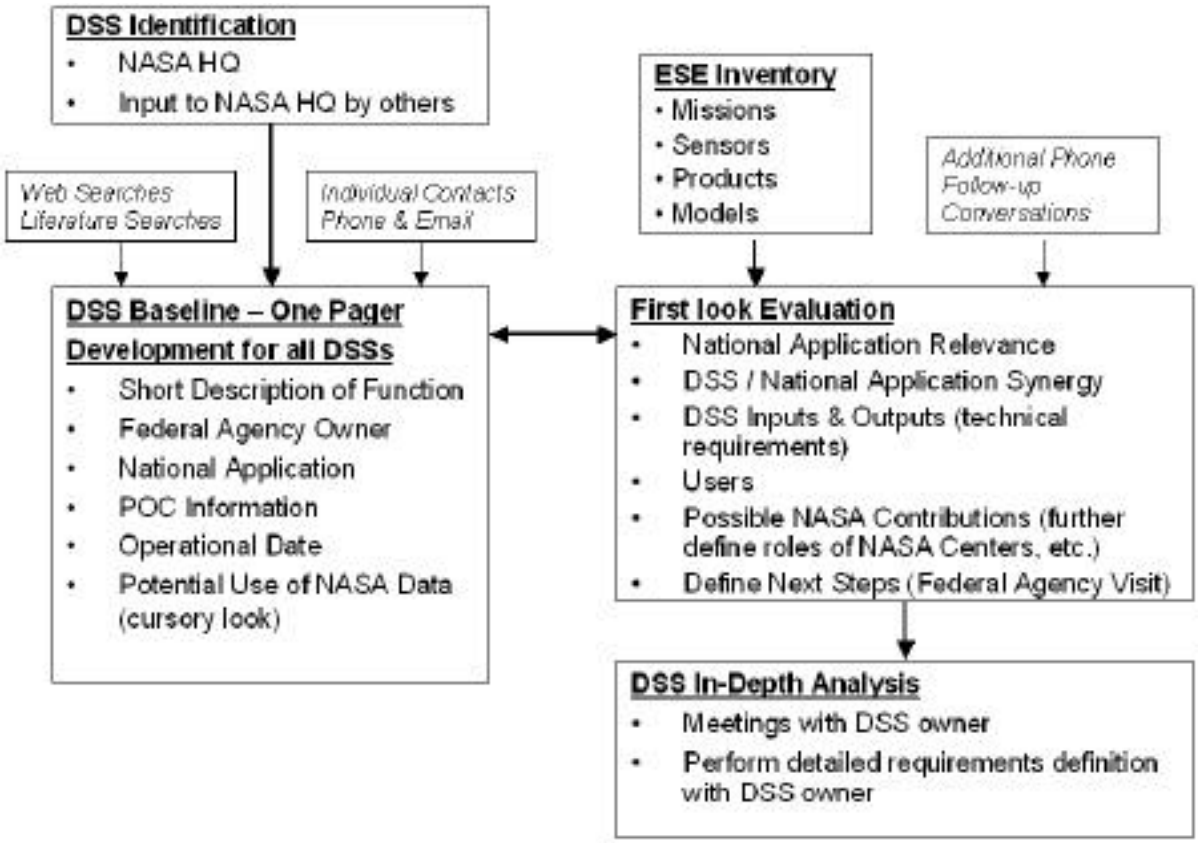


Figure 3. SSC evaluation steps.

2.2 Results of First-look Evaluations

The ESA Directorate has conducted first-look evaluations for several DSSs identified by NASA HQ:

- Crop Condition Data Retrieval and Evaluation (CADRE) for *Agricultural Efficiency*,
- Hazards U.S. (HAZUS) for *Disaster Management*,
- Agricultural Water Resources and Decision Support (AWARDS) for *Water Management*,
- RiverWare for *Water Management*,
- Community Multi-Scale Air Quality Modeling System (CMAQ) for *Air Quality*,
- Harmful Algal Bloom (HAB) Mapping System and Bulletin for *Coastal Management*.

Some of the first-look evaluations were requested by the application program managers, while the others were undertaken to build SSC's knowledge and capacity to support assimilation of NASA inputs within the various application areas. Brief descriptions of the DSSs and results of the first-look evaluations are provided below. Complete presentations regarding the first-look evaluation results are included in Appendix E.

CADRE/PECAD is a geospatial database management system used by analysts of the U.S. Department of Agriculture (USDA), Foreign Agricultural Service (FAS), Production Estimates and Crop Assessment Division (PECAD) for assessments of global crop conditions and for estimates of area, yield, and production for grains, oilseeds, and cotton. Datasets stored in CADRE include daily meteorological observations from weather stations and satellites, crop modeling results, and remote sensing imagery/products from the following satellite sensors: the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), and SPOT VEGETATION. During the first-look evaluation, it became apparent that CADRE is only one part of a broader decision-making environment at PECAD. That environment can be enhanced with several MODIS land data products as well as with precipitation and rainfall data from the Tropical Rainfall Measuring Mission (TRMM), a joint effort of NASA and the National Space Development Agency of Japan.

HAZUS is a natural hazard loss estimation methodology supported by the Federal Emergency Management Agency (FEMA) and implemented through PC-based geographic information system (GIS) software. HAZUS was first developed to assess the effects of earthquakes but has now expanded to include models to address flooding and wind (hurricane) hazards (multi-hazard methodology: HAZUS-MH). HAZUS is mainly used by federal, state, and local government officials for risk assessment and mitigation planning. The first-look evaluation determined that the best opportunity for NASA contribution would be in validation of an improved wind damage model being developed for HAZUS. The validation is based on comparison of surface roughness estimates based on digital elevation models (derived from Light Detection and Ranging, Interferometric Synthetic Aperture Radar, or aerial photography measurements), flux tower anemometer measurements, and land cover/land use models derived from high-spatial-resolution remote sensing imagery.

AWARDS has been developed by the Bureau of Reclamation of the U.S. Department of the Interior. This DSS improves the efficiency of water management and irrigation scheduling by providing guidance on when and where to deliver water and how much to apply. It is based on data streams from the Next Generation Weather Radar, or NEXRAD, radar network (hourly precipitation and daily

rainfall) and the NOAA weather stations (daily observations). Reservoir system operators, water district managers and staff, and irrigation organizations use AWARDS system products via the Internet to make operational decisions. The ET Toolbox extension of AWARDS generates evapotranspiration estimates and provides water use inputs for the RiverWare DSS that supports water management decisions. NASA is already involved in the AWARDS enhancements through the Land Data Assimilation System group at the Goddard Space Flight Center. This group is working on integration of the North American Land Data Assimilation System into the ET Toolbox to improve water operations. Another NASA contribution may be in the form of validation of the evapotranspiration estimates based on cross-comparison of AWARDS/ET Toolbox predictions with flux tower measurements and model calculations derived from remote sensing imagery.

RiverWare is a flexible general river basin modeling tool that allows water resources engineers to simulate and to optimize the management of multipurpose reservoir systems. The software was developed at the University of Colorado with support from the U.S. Bureau of Reclamation (USBR) and the Tennessee Valley Authority (TVA). The USBR has replaced both its long-term policy and planning model (Colorado River Simulation System) and its mid-term operations model (24-Month Study) for the Colorado River with RiverWare rule-based simulation models. These models are used for policy negotiations, for estimating future salinity mitigation needs, and for setting the monthly target operations for the entire river basin. The TVA uses RiverWare in simulation and optimization modes for daily scheduling of more than 40 reservoirs and hydroelectric plants. Operating considerations include controlling floods, maintaining navigable depths, protecting aquatic communities, providing suitable levels and releases for recreation, and achieving economical hydropower generation schedules. Many other federal, state, and local government agencies also use the RiverWare software for water management purposes. First-look evaluation results suggest that NASA measurements of air temperature, solar irradiation, and precipitation may enhance this DSS.

CMAQ has been developed by the Environmental Protection Agency (EPA) for modeling of multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. CMAQ is designed to have multi-scale capabilities so that separate models are not needed for urban-scale and for regional-scale air quality modeling. CMAQ is used by many government agencies and by other organizations both in the United States and abroad. Many NASA-generated datasets are already used in CMAQ, but CMAQ might assimilate additional NASA measurements, such as those of atmospheric particles and trace constituents as well as of extraterrestrial irradiation.

HAB Mapping System and Bulletin: The HAB Bulletin provides information to the management community in the Gulf of Mexico during a bloom event. HABMapS is an interactive mapping tool that can be used to access recent data on harmful algal blooms in the Gulf of Mexico and on the environmental conditions that may affect the spread of these blooms. Both tools rely on remote sensing technology to provide the large spatial scale and high frequency of observations required to assess bloom location and movements. These tools can be used together to provide a regional perspective on harmful algal bloom events.

Additional first-look evaluations were conducted in support of the Coastal Management National Application. To expand the opportunity pool of DSSs considered for enhancement with NASA data, the following decision support systems and tools were investigated:

- Better Assessment Science Integrating point and Nonpoint Sources (BASINS),

- Coral Reef Environmental Warning System (CREWS),
- General NOAA Oil Modeling Environment (GNOME),
- Protected Area Geographic Information System (PAGIS),
- ReefBase,
- System on AWIPS for Forecasting and Evaluation of Seas and Lakes (SAFESEAS),
- Spatial Wetland Assessment for Management and Planning (SWAMP),
- Water, Soil, and Hydro-Environmental Decision Support System (WATERSHEDSS).

Among these DSSs, ReefBase has the greatest potential to benefit from NASA contributions. ReefBase is owned by the World Fish Center, an autonomous, non-governmental, nonprofit, international scientific and technical center organized to conduct, stimulate, and accelerate research on all aspects of fisheries and other living aquatic resources. The operational concept of ReefBase includes development of a relational database for structured information on coral reefs that will serve as a computerized encyclopedia and analytical tool for use in reef management, conservation, and research. NASA contributions to the ReefBase enhancement may consist of supporting an ongoing effort to populate ReefBase with satellite and aircraft imagery of the world's coral reefs and developing standard indicators (based on satellite imagery) of reef health, productivity, and economic value.

During FY2003, ESA Systems Engineering also supported evaluation and, in some instances, benchmarking of decision support systems and tools for the Public Health and Air Quality National Applications as well as those utilized by the TVA. The Public Health Applications Team activities were described in the SSC FY2003 Report of Activities. Initial technical meetings were held with representatives from the Center for Disease Control and Prevention's (CDC) National Center for Infectious Disease (NCID) and National Center for Environmental Health (NCEH). Each group met with NASA separately to evaluate and discuss technical requirements, capabilities, and areas of opportunity for collaboration whereby Earth science and remote sensing could be used for public health decision support. Reports of Findings from both meetings were generated for NASA HQ program planning purposes. Benchmarking of MODIS data products for Air Quality Index PM2.5 Forecasting is currently underway, and an ESA team will document these efforts by November 2003. Another ESA team investigated the potential for collaborative projects between NASA and the TVA under those National Applications of interest to the TVA. NASA observations of atmospheric trace gases and surface temperature were considered as inputs to DSSs and DSTs used by the TVA. A prototype data product that incorporates information from NASA data has been developed as well.

2.3 In-depth Evaluation and Reverse Engineering

After a first-look evaluation was completed and evidence suggested that the DSS had potential to benefit from NASA observations and predictions, an in-depth evaluation began in partnership with the DSS owner (Figure 4). The FY2003 activities were concentrated on conducting in-depth evaluations for two DSSs: HAZUS and CADRE/PECAD. The DSS missions were researched thoroughly to determine their operational requirements, funding profiles, relationships to the national applications, relevance of NASA capabilities, and understanding of DSS applicability to NASA partnership criteria as defined in the ESE Applications Strategy (NASA, 2002a). Once these items were addressed, the DSSs were reverse engineered by NASA personnel to develop specifications that

could improve the DSS solutions, identify important measurements and models, and assess existing NASA assets (Figure 5). During this phase, the NASA team answered questions such as these:

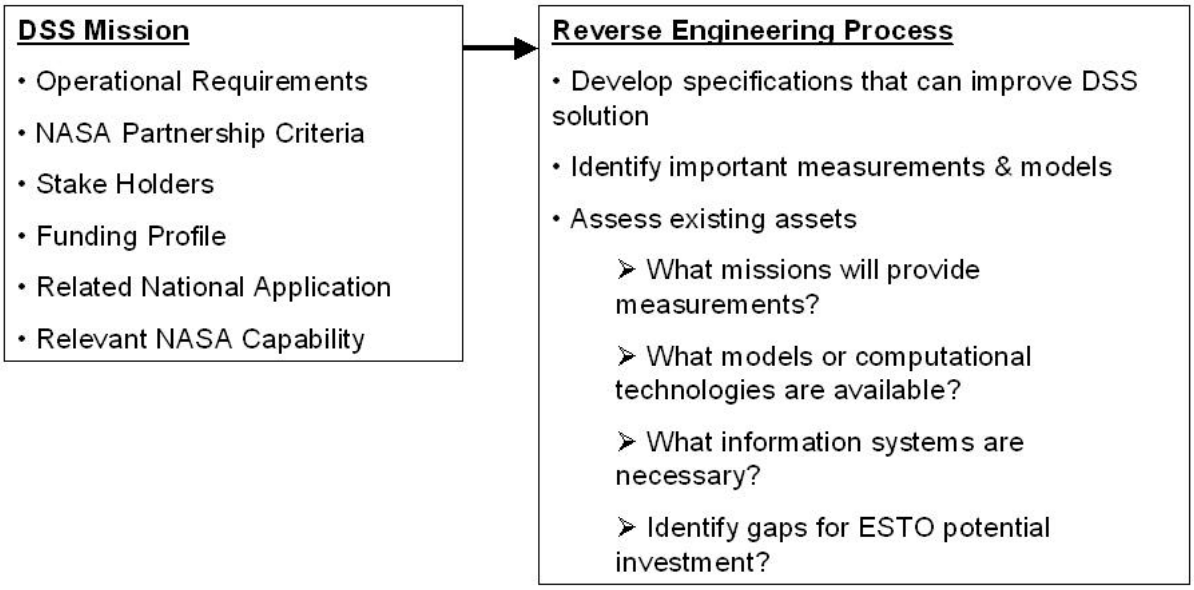


Figure 4. In-depth evaluation.

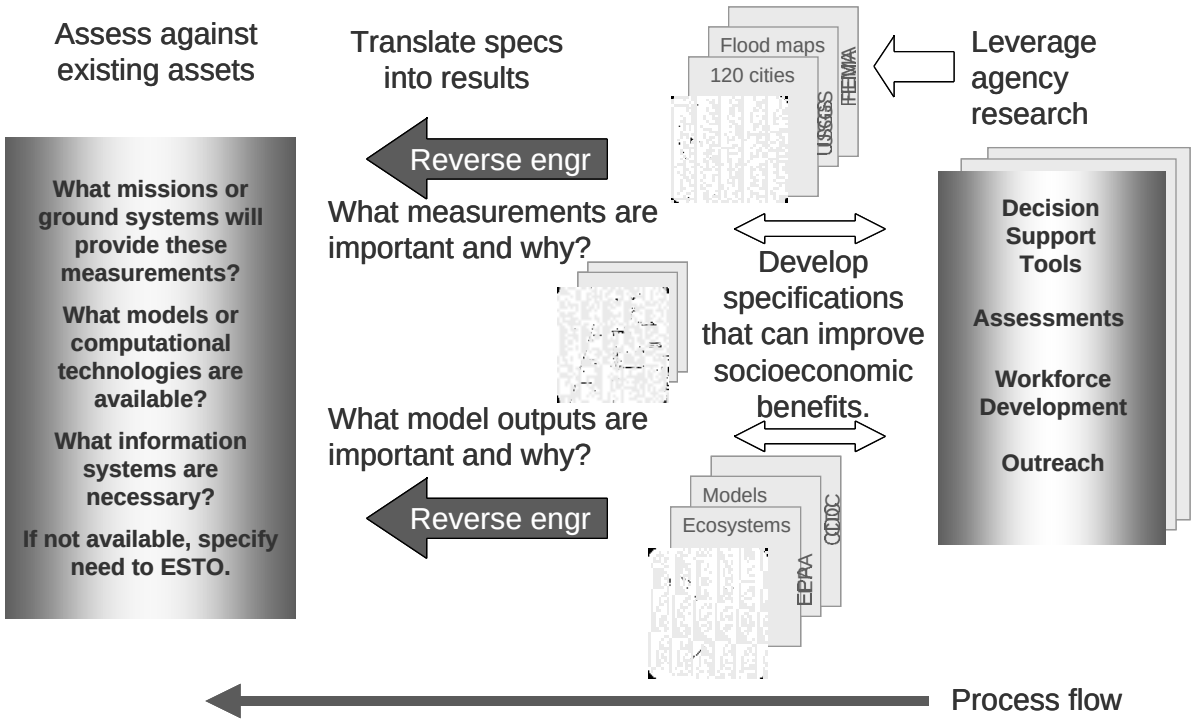


Figure 5. Reverse engineering paradigm (NASA, 2002a).

- What missions will provide measurements?
- What models or computational technologies are available?
- What information systems are necessary?
- How can NASA data, products, or models be modified to serve better the needs of the DSS?

As part of this process, alternative NASA inputs were also investigated that helped uncover key drivers and gaps in meeting DSS needs and requirements. These insights are intended to serve as feedback to the Earth Science Technology Office (ESTO) for potential future investments.

Each complete evaluation process was documented with a report that defined the baseline DSS, described requirements for improvements, and identified NASA products and models to be incorporated. The evaluation reports were based on the following outline:

- Background description of DSS: What is it? How does it work? Who uses it?
- Detailed description of DSS: Architecture, modules, inputs, outputs, technical details, etc.
- Possible NASA inputs and description of how inputs would be used
    - Discussion of all the possible measurements and predictions, including those for which specific implementation plans exist

    - Planned data flow charts when available

- Identified NASA technology gaps in meeting DSS needs
- Recommendations/Next Steps:
    - Preliminary (conceptual) plans for implementation, V&V, and benchmarking of the DSS

The evaluation reports created for the PECAD/CADRE and HAZUS DSSs are provided in documents separate from this report.

2.4 Verification, Validation, and Benchmarking

As described above, the majority of FY2003 activities centered on beginning the evaluation of several DSSs. In addition, initial processes for the V&V and benchmarking phases have been defined as outlined in Figure 6.

The V&V component to this systems engineering approach is closely connected with the design and implementation phase. During this phase, NASA capabilities are integrated into the DSS to generate products, solutions, and outputs. To ensure the quality of the output, results are verified by comparison with technical specifications using *in situ* measurements and cross-comparisons with other DSSs, models, and data sources. Furthermore, NASA then interacts with the end users to validate whether the outcome of the enhanced DSS meets the functional desires of the DSS owner.

In general, verification and validation conducted in support of the National Applications occurs on three levels:

- Data Product V&V,
- Model and Algorithm V&V, and
- DSS V&V.

The V&V process levels may be viewed collectively as a pyramid, shown in Figure 7, with the Data Product level as a foundation and with the DSS level at the top. In this sense, data products must be well understood and characterized to provide meaningful input into NASA's models and algorithms, which must be verified and validated before they are input into DSSs. DSSs in turn must be verified and validated to ensure they are meeting national needs and requirements.

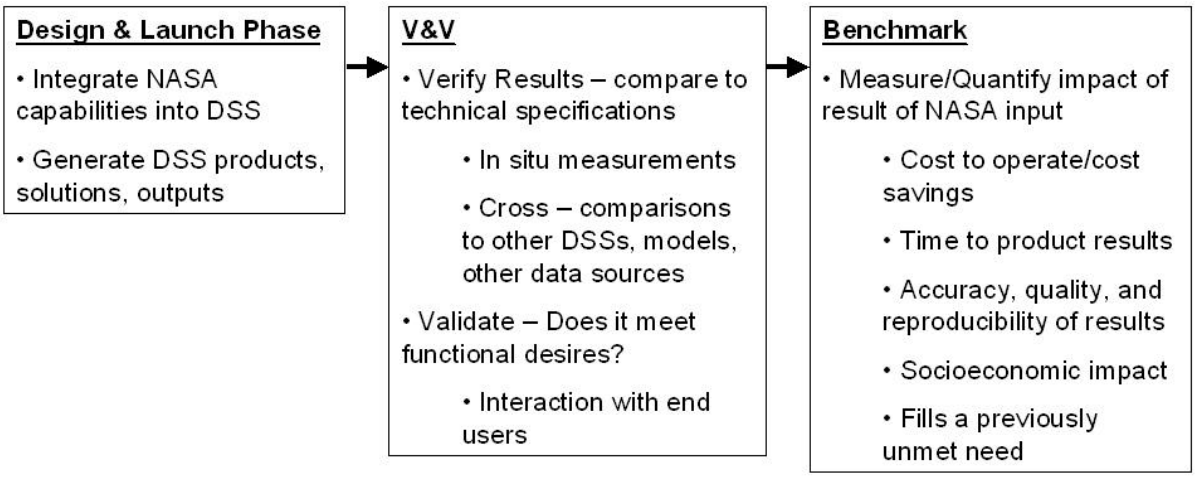


Figure 6. V&V and benchmarking phases.

V&V activities undertaken on the Data Product level investigate resolution and accuracy of data products derived from observations made with sensors deployed during ESE missions or from predictions made with Earth system modeling and simulations. These V&V activities are a critical step in the V&V process because all subsequent steps build upon this foundation. As part of these V&V activities, interaction with the ESE Earth Observing System (EOS) calibration/validation (cal/val) community will take place to understand and translate better the state of the ESE data product validation. New NASA products may be developed that are specific to a particular DSS, and they must be validated as well.

On the Model and Algorithm level, V&V activities focus on determining that a model implementation accurately represents the developer's conceptual description and specifications, and that the model is an accurate representation of the real world from the perspective of the intended uses of the model. In these activities, simulated data products are often used instead of actual products to control key data product parameters and to study their effects on model predictions. The simulated data products can be generated with such tools as the Applications Research Toolbox (ART) (Zanoni, 2002). While validation on the Data and Product Characterization level can be seen as a process of validating direct results of observations, validation on the Model and Algorithm level can be thought of as a process of validating indirect results and predictions created from the observations. In this sense, the Model and Algorithm level validation also requires conducting advanced laboratory and field experiments supported by state-of-the-art instrumentation (Ryan, 2002). NASA has been conducting such work as part of the Scientific Data Purchase V&V and EOS cal/val team activities and is well equipped to support it in the future (Pagnutti, 2002).

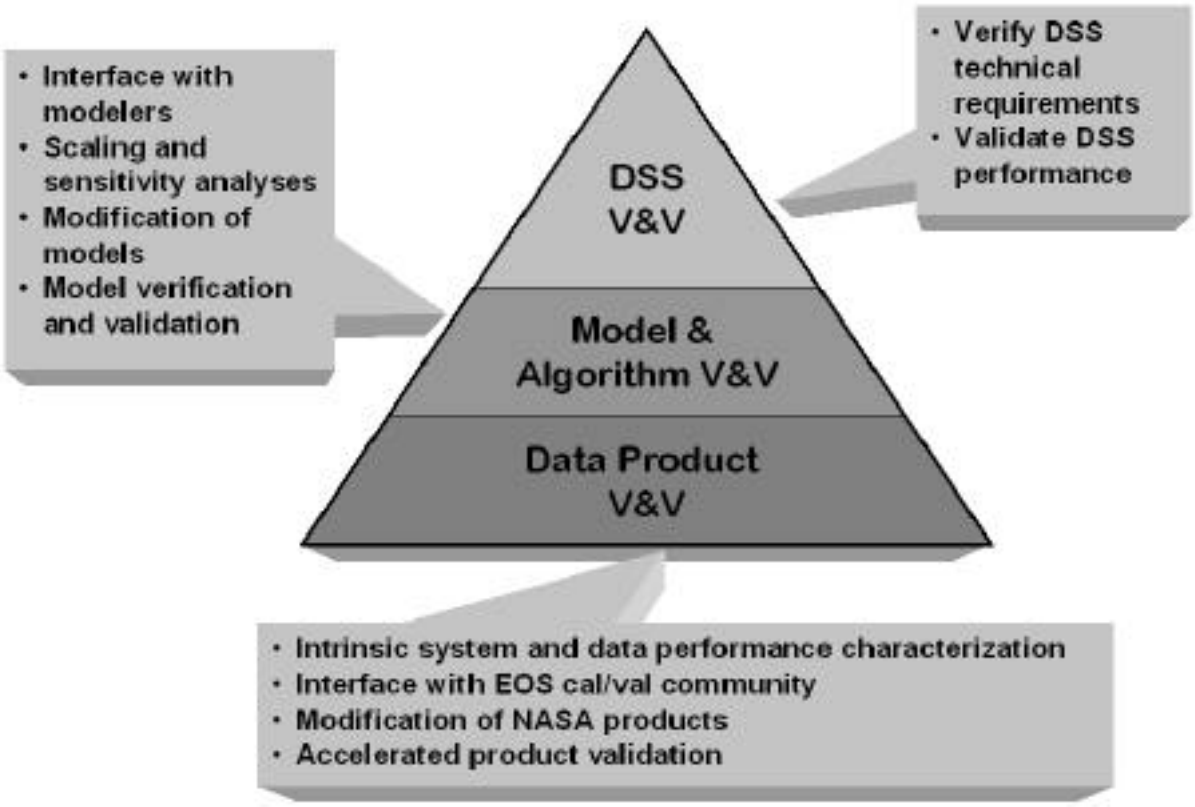


Figure 7. V&V pyramid.

On the DSS level, V&V activities focus more on the software engineering methods discussed above. As the DSS enhancements are undertaken in partnership with other federal agencies and organizations, methods used by the DSS owners to verify and validate outputs of their DSSs are applied again to the DSS enhanced with NASA inputs. While DSS operations rely on processing of many datasets and on combining outputs of many models, some direct field experiments may still be conducted to validate the enhanced DSS results.

When the DSS is a computer program that analyzes and presents data so that users can make decisions more easily, then V&V of the DSS can be based on testing methods developed for software engineering. To perform its functions of analyzing and representing data, such a DSS incorporates a model of the realm for which the decision-making takes place. In this context, verification of the DSS is a process of determining that a model implementation (coding) accurately represents the developer's conceptual description and specifications, while validation is a process of determining the degree to which the model is an accurate representation of the real world from the perspective of the intended uses of the model (DoD, 2003). V&V of the DSS enhancement involves only those parts of the software that are being enhanced by assimilation of NASA ESE data and products. The V&V processes intertwine with the process of implementing the enhancements and include the following steps:

- When rudimentary functionality for using ESE datasets is implemented in the DSS, experiments with small representative datasets are conducted.
- After functionality for using the ESE datasets in the DSS is improved, experiments with full-scale datasets are performed.
- With functionality for using ESE datasets in the DSS adjusted to conform to NASA data interfaces, experiments with actual datasets using simulated interfaces to existing ESE systems are conducted.
- When a prototype of the enhanced DSS is completed, validation and benchmarking with actual datasets in the simulated environment can be performed.
- In the final V&V step, the prototype of the enhanced DSS is made available for demonstration and testing using operational interfaces to ESE datasets.

The final component to this systems engineering approach involves benchmarking the enhancements made by NASA on the partner-owned DSS. During this final phase, the impact of NASA input on the DSS output is measured and quantified. The measurements include such tangibles as the cost to operate; the time to produce results; the accuracy, quality, and reproducibility of DSS results; the socioeconomic impact; and the enhanced DSS's ability to fill a previously unmet need of the DSS owner.

Benchmarking of a DSS is a process of measuring the performance of the DSS according to specified standards and reference points to document its value and to identify areas for improvements. A *benchmark* denotes a widely recognized reference point by which performance of other systems is measured, compared, and evaluated. If a standard reference point does not exist, then benchmarking refers to measuring the performance to establish a standard of reference. In the case of DSS enhancements, assessing performance of an original DSS without enhancements being implemented first creates the baseline benchmark, and then performance of the enhanced DSS is assessed and compared with the baseline.

The benchmarking component should make use of existing techniques widely used within the community that owns the now-enhanced DSS. These existing techniques need to be reviewed, understood, and possibly augmented to ensure that they properly measure the NASA enhancements before they are used as a tool. By embracing partner benchmarking tools and techniques, NASA ESE improves the likelihood that our partners will become familiar with the benchmarking process and results, accept the results, and take ownership of the results. In addition, making use of already existing applicable benchmarking techniques is a more cost-effective way of measuring the enhancements that NASA ESE has made to the DSS.

3.0 Lessons Learned

The SSC FY2003 evaluation activities have produced several lessons learned, which are described below in no particular priority or order of importance.

Lesson 1. Successful use of NASA observations and predictions within DSSs often evolves from existing science research performed in collaboration with agency partners.

NASA is already involved with some DSSs. For example, some of the MODIS Science Team members and their peers are either directly or indirectly collaborating with owners of DSSs using MODIS data. The MODIS Land Rapid Response system for forest fires monitoring, in collaboration with the U.S. Forest Service, is the best example of such work. Some of these and other heritage efforts should be mined and aligned with the new National Applications approach to continue the most successful activities and leverage from existing research and relationships.

Recommendation: Identify and continue supporting existing, DSS-related NASA projects that produce valuable results.

Lesson 2. The greatest opportunities for integrating NASA data into DSSs are often found with DSSs that are in early development stages.

Most of the DSSs examined are mature. It is sometimes more difficult to insert NASA data into mature systems for the following reasons:

1) Limited flexibility in the DSS to allow integration of alternate data sources with scale and data formatting issues.

2) Resistance from operational users. When a DSS is being used operationally, the owner/user may be hesitant to introduce any changes in the input for fear of the resulting changes in the output.

On the other hand, if the DSS developers are introduced to the NASA data early in the DSS's development, the DSS can be built with NASA data/models in mind and the DSS can grow with the NASA data, maturing into a product with which the owner/user is comfortable. This fact is illustrated by the development of some of the DSSs where the developers made that linkage with NASA's data early on. For example, NOAA's HABMapS uses satellite data from NASA's QuikSCAT SeaWinds instrument to help monitor harmful algal blooms in the Gulf of Mexico. Thus, to make the most significant impact on a DSS it is best to get involved in the embryonic stage of development and work through the process (typically 5 to 7 years) with the collaborators and DSS developers. To insert NASA into a DSS at the end of the process will normally be very difficult.

Recommendation: Seek opportunities to work with DSSs in their early stages. Examples: ReefBase, the Environmental Public Health Tracking Network (EPHTN), and HAZUS-MH.

Lesson 3. Many of the currently identified DSSs do not fit the Applications Program definition of DSS (Appendix A).

A majority of the DSSs studied do not perform a decision-related function, such as applying a model or performing analysis. They simply incorporate data into a GIS environment to make the data easier to view. Decisions are supported only in the sense that being able to view data at common scales and in a user-friendly environment makes life easier for a decision-maker. In addition, many DSSs fall into

the category of outreach. Agencies have outreach activities that seek to generate interest in their functions by students and the public. Many of the DSSs appear to satisfy an outreach role, but they do not support operational decisions. NASA's systems engineering team cannot anticipate the array of "decision-making capabilities" that it will encounter in the future. For example, primary role of human element (analysts) in the PECAD decision support process makes quantitative benchmarking more difficult. However, the team will learn to make the distinction between actual DSSs and other management tools that do not fit the Applications Program definition of a DSS.

Recommendation: In addition to the term "DSS," use terms such as "decision support tools," "decision support environment," "decision making processes," and others to describe more accurately the tool being evaluated. Ensure that definitions of the new descriptive terms are documented for use with similar procedures in the future. Additionally, when the evaluation team encounters a tool that does not support decision-making or fit the definition of a DSS, it should seek guidance on NASA's interest in participation.

Lesson 4. **It is often difficult to gain access to the appropriate persons to understand DSS operation and technical requirements.**

To truly understand a DSS's operation and technical needs, detailed conversations with DSS developers and operators are required. In many cases, programmatic issues have caused delays in identifying the appropriate persons and in scheduling detailed discussions. In these cases, the NASA systems engineering teams have used the Internet and other public sources to access information. However, the Internet can be a misleading source of information. Many Web pages are out of date by several years.

Recommendation: Empower the NASA system engineering teams to establish personal contacts for accessing detailed DSS information.

Lesson 5. **Synergy exists between many DSSs and applications.**

Public Health and Air Quality overlap in that poor air quality (e.g., smog, ozone) has a negative impact on respiratory health. Water Management practices impact irrigation potential for Agricultural Efficiency, and agricultural practices (e.g., use of fertilizer) affect water quality. Many opportunities exist to find cross-cutting solutions to multiple applications and DSSs. Identification of synergies has been enabled by an independent systems engineering team providing support to all applications and DSS evaluations.

Recommendation: Continue to have an overall systems engineering team that provides support to all applications so that NASA can identify opportunities to exploit synergy as a third-party broker between related DSS and application partners.

Lesson 6. **The process to bring R&D technology and products to operational use requires significant investments of time and funds.**

NASA products have been designed to answer science questions at a global scale and not necessarily to support operational applications that often have regional or location-specific requirements. For example, many MODIS products are several-day composites gridded at spacings much greater than the intrinsic data. For many regional problems it will be advantageous to have 1 km resolution or better products produced daily or in near real time. In other cases, applications research activities are needed to bring NASA measurements and model outputs into DSSs. These examples require funding and time for applications research, new product development, and V&V before integration within a DSS can begin.

Recommendation: Create rapid prototype product capability that can develop new application-specific products to be generated by direct broadcast receiving stations or the current Distributed Active Archive Centers (DAACs).

Recommendation: Provide seed funding for applications research to move NASA research outputs into operational environments.

Lesson 7. DSS technical requirements and specifications are difficult to identify.

DSS owners/operators may not have a complete understanding of the technical requirements for remotely sensed data and information. Very few systematic studies have been performed that produce true input specifications for DSSs. For example, the data types and the remote sensing requirements for spatial, spectral, and temporal resolutions are not well known for many applications. This creates difficulty in understanding the needs of the DSS and the limitations of proposed data sets/products *a priori*. The lack of requirements definition limits the ability to select appropriate technologies to meet DSS needs and to make recommendations to ESTO about the specifications of new systems.

Recommendation: NASA must take the lead in working with other agencies to develop specifications for improvements/enhancements or for development of new DSSs.

Lesson 8. NASA scientists in residence at operational agencies (or other agency scientists resident at a NASA center) can foster the incorporation of NASA inputs into operational environments.

As mentioned in Lesson 6 above, new product development and/or applications research is often needed to transition a NASA research output into an operational DSS input. This type of research, done collaboratively with a partner agency, can be greatly facilitated by resident scientists from NASA working together on a daily basis with operational users to understand technical requirements, and to develop and test NASA inputs to serve partner needs.

Recommendation: NASA should leverage from and seek opportunities for detail assignments with partner agencies to further accelerate applications research and operational use of NASA observations and model predictions.

Lesson 9. **DSS owners and DSS users are not always the same entity. Frequently the user/analyst involvement will impact the DSS's operation in ways the owner/developer will not have anticipated.**

There are instances where the DSS developer is not the user (or at least not the only user) of the DSS they develop. For example, RiverWare is owned and used by the U.S. Bureau of Reclamation and the Tennessee Valley Authority. It is supported, maintained, and continually enhanced by the University of Colorado's Center for Advanced Decision Support for Water and Environmental Systems. However there are 19 other separate RiverWare users identified in Appendix E. A similar scenario is true for HAZUS. All of these stakeholders influence the operation of the DSS and are potentially impacted by changes in the DSS. They should be represented in the evaluation, V&V, and (especially) benchmarking processes.

Recommendation: Form additional partnerships with users of the DSS so effective and truly representative benchmarking can be done.

Lesson 10. **NASA ESE Applications Program definitions for key terms, such as systems engineering, evaluation, assimilation, and benchmarking, are not always consistent with commonly accepted use of these terms.**

Some NASA definitions are confusing to partner agencies and operational users. In addition, a certain amount of inconsistency exists within the NASA Applications teams on the use of these terms. In most cases, commonly accepted definitions can be found through simple Internet and literature searches.

Recommendation: NASA should develop a simplified set of key terms and definitions that are consistent with commonly accepted (i.e., outside of NASA) uses of such terms.

4.0 Key Drivers and Gaps

While many current observations from NASA missions and predictions from NASA-supported computational models can be used to enhance decision support systems and tools from other agencies, some gaps in meeting DSS needs still exist. General technology gaps are briefly discussed below. Gaps in more specific technologies are described separately in the specific DSS evaluation reports.

System Redundancy: Partner agencies with operational DSSs are naturally concerned about redundancy in crucial data sources. Agencies that rely on DSSs (and on the data that feed them) cannot afford an unrecoverable loss of data. When any critical source of data fails, a replacement system must continue to provide the necessary data for the DSS and for the partner agency. If NASA’s data sources were to be critical to the DSS’s operation, NASA would have the same constraints. Partner agencies are concerned about the lack of backup systems to NASA data sources. Consider, for example, that Landsat 7 ETM+ has only an inferior backup system provided by Landsat 5 TM versus the redundancy in weather satellites such as NOAA’s Geostationary Operational Environmental Satellites (GOES) and Polar Operational Environmental Satellites (POES) (not to mention the Defense Meteorological Satellite Program, Meteosat, etc.). If one of these satellites fails, another satellite is typically in preparation for launch. Such operational backup systems do not exist

for most NASA EOS satellites. The thought is that many NASA measurements can provide data for applications research, but not for applications operational deployment.

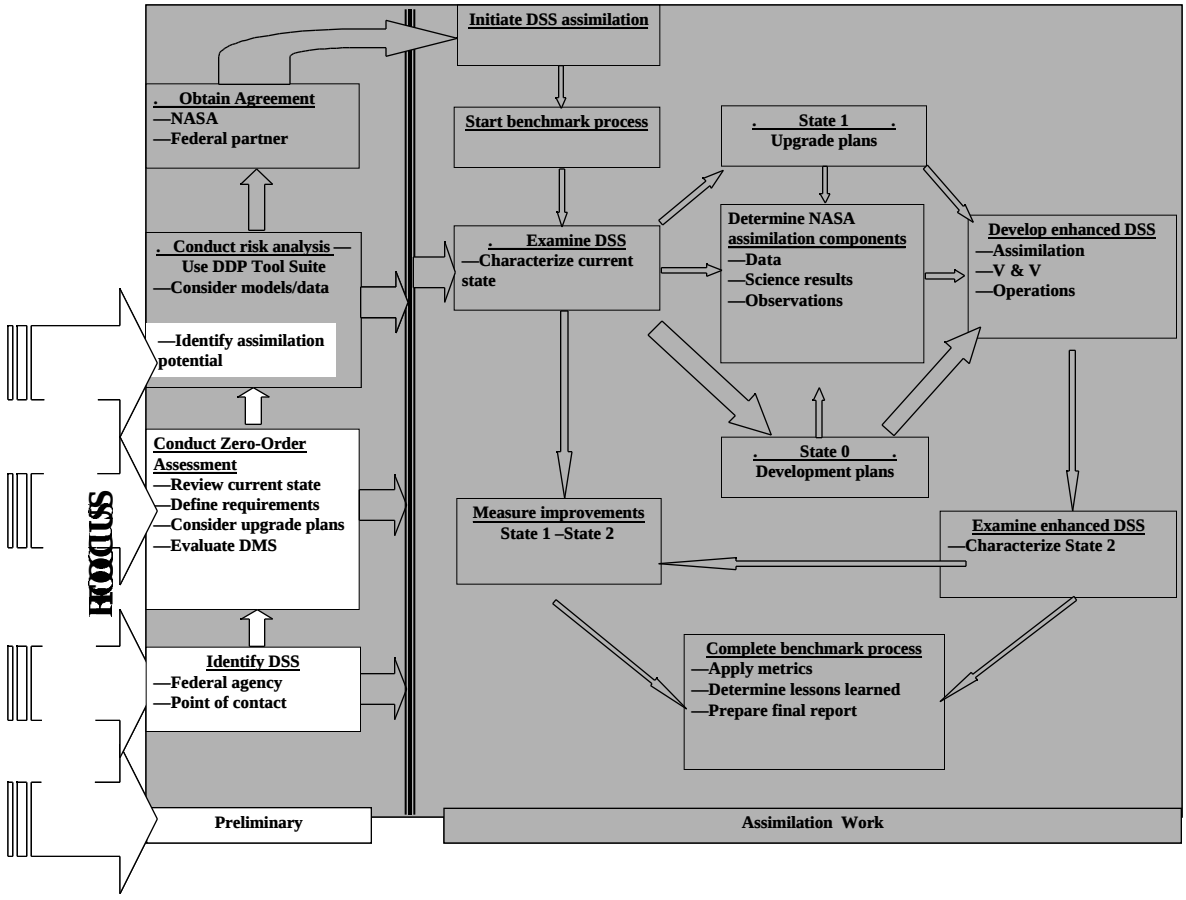
System and Product Continuity: Incorporation of NASA inputs into an operational environment will also depend on the long-term availability of that input. Partner agencies are often concerned that there is little continuity in NASA data sources, and termination of a current mission results in an unrecoverable loss of data for the partner agency. For NASA input data to be accepted into an operational DSS, a follow-on mission (satellite, sensor) must be clearly defined and a commitment to the mission must be made. Alternatively, some partners are more concerned with "product continuity" rather than "system continuity." For example, a partner interested in using a data product currently available from a short-term mission/sensor might be satisfied with a similar product created from another mission/sensor available in the long-term. Referring to the weather satellites again, although neither GOES nor POES can perform the other's job as well as its own, the meteorological community does not hesitate to use data from either satellite if the other fails and critical data for operational forecasts is needed. Moreover, commercial and foreign data sources also have potential to fill gaps in system and product continuity.

Data Size and Format: The EOS data format is not easily incorporated into many operational environments. Besides data in the HDF/HDF-EOS format, ESE datasets should be produced in formats more widely accepted in the GIS software. In addition, partner agencies often desire reasonably sized datasets that can be easily managed and manipulated without requiring state-of-the-art computational systems. A solution to this problem may be a new, applications-oriented DAAC that will process (reformat) and resize the datasets and will distribute them to partner agencies and local/state government users.

Thermal IR: Many operational applications use thermal infrared (TIR) or mid-wave infrared (MWIR) data, although traditionally TIR has been used more than MWIR. For example, TIR data is used for evapotranspiration measurements in agricultural monitoring. TIR data can also be used by water management agencies such as the TVA to monitor water temperatures in power plant operations. MWIR data is useful in forest fire management because it can see through smoke and identify hot spots. MODIS provides a source of MWIR data that should continue into the near future; however, TIR support is not scheduled to continue. Many applications, such as agricultural monitoring, depend on this type of data and will be affected by lack of follow-on to the Terra Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor and lack of the thermal IR band in the Landsat Data Continuity Mission (LDCM). NASA must invest in TIR satellite observations with moderate spatial resolution (<100 m GSD).

System Specifications: Application needs must be taken into account when specifications for a new mission are developed. Many NASA missions could provide very useful measurements for the National Applications, but such crucial mission specifications as coverage area, revisit time, and spatial resolution are insufficient for the application requirements. For example, the TRMM rain measurements could be even more useful if available for higher latitudes, and future Landsat datasets would find more applications if produced with a revisit time shorter than 16 days by using multiple Landsat satellites on shifted orbits.

Product Timescales: Many NASA data products are produced on timescales that are not consistent with the needs of a given DSS. For example, certain MODIS data products that have potential application in the PECAD agriculture decision-making environment are produced on 8- and 16-day timescales. However, PECAD uses a 10-day timescale to produce its agricultural production



estimates. In such cases, investments in new product development (e.g., a 10-day MODIS product) may be necessary to meet the needs of operational users.

5.0 Proposed DSS Selection, Evaluation, V&V, and Benchmarking Processes

Based on experiences and lessons learned in FY2003, an improved process for selection, evaluation, verification and validation, and benchmarking of DSSs is proposed. The proposed process is presented here in two parts: the DSS selection process and the DSS evaluation, verification & validation, and benchmarking process.

5.1 DSS Selection Process

Figure 8. Assimilation approach (Kaupp et al., 2003).

The objective of the DSS selection process is to establish a disciplined, analytical approach for determining which opportunities offer the best chance for successful assimilation of NASA science, data, technology, and/or models that meet DSS requirements and offer significant enhancement of DSS capabilities. The selection process focus is the preliminary stages of the "Approach To Assimilation" proffered by Kaupp et al., 2003 (Figure 8). The major objectives of the preliminary stages are to identify DSSs, to conduct zero-order assessments, and to identify the assimilation potential of the NASA-offered observations and predictions. As will be seen, the selection process discussed in this section aligns with the concepts embodied in the cited reference.

5.1.1 Opportunity Identification

The selection process begins by identifying opportunities and candidate DSSs that may benefit from the assimilation of NASA observations and predictions. Opportunity identification can/will come from a wide variety of sources (see Figure 9). Few if any restrictions are applied at this juncture. The goal is simply to collect general information (e.g., technical and non-technical, name, location, intended purpose) concerning the DSS. The information sources are equally unrestricted. Virtually anyone who has an interest in the DSS, the problem it addresses, and/or the science technology involved may provide input, which develops a potential opportunity pool from which to begin the selection process. This open method of collecting DSS identification information will soon yield a large number of potential opportunities, which burdens the methodology with selecting a high-quality subset that offers high potential for success. Succeeding paragraphs discuss that methodology.

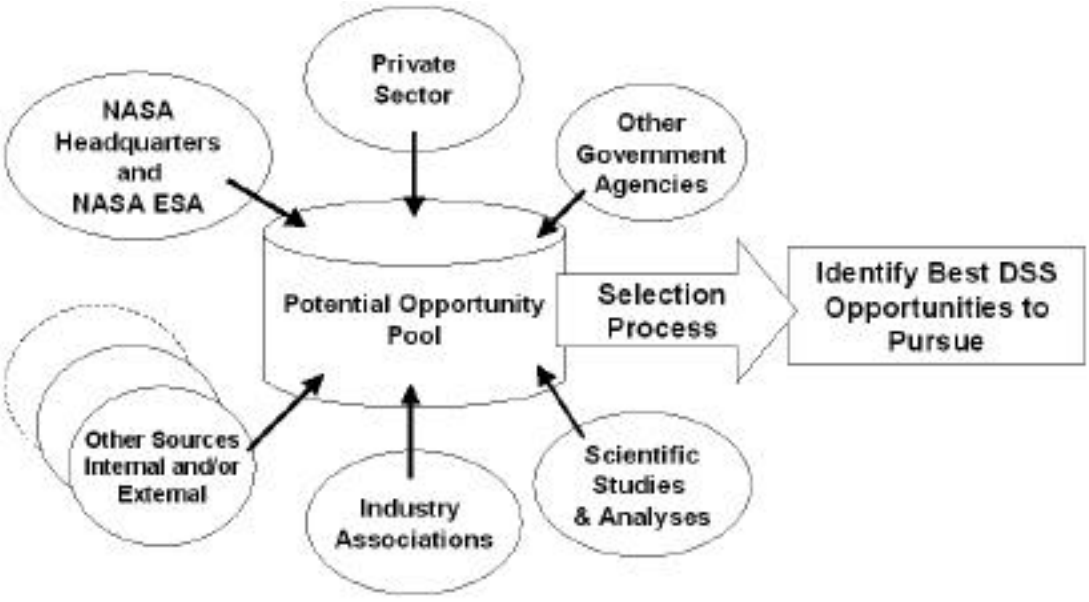


Figure 9. DSS opportunity identification.

5.1.2 Selection Steps

The DSS selection process is based on lessons learned from working DSS-related issues during FY2003 (the Baseline) and from a model[2] for business development used in the aerospace and defense industry for the front-end analysis of business opportunities. In the latter process, *the front-end analysis focuses on selecting opportunities with the highest probability of success*, which is precisely the issue faced regarding the selection of DSSs wherein the assimilation of NASA science, data, technology, and/or models offers the best chance of success. As depicted in Step 1 of Figure 10, the process begins with the NASA Assimilation Team (AT), which has responsibility for the entire process, investigating the DSS opportunity pool to identify specific opportunities that appear to have a high probability of successful assimilation of NASA observations and predictions. This decision will be based primarily on the requirements of the DSS, as driven by its mission, goals, and/or objectives. The key question is: "Can NASA science, data, technology and/or models help in meeting DSS requirements?"

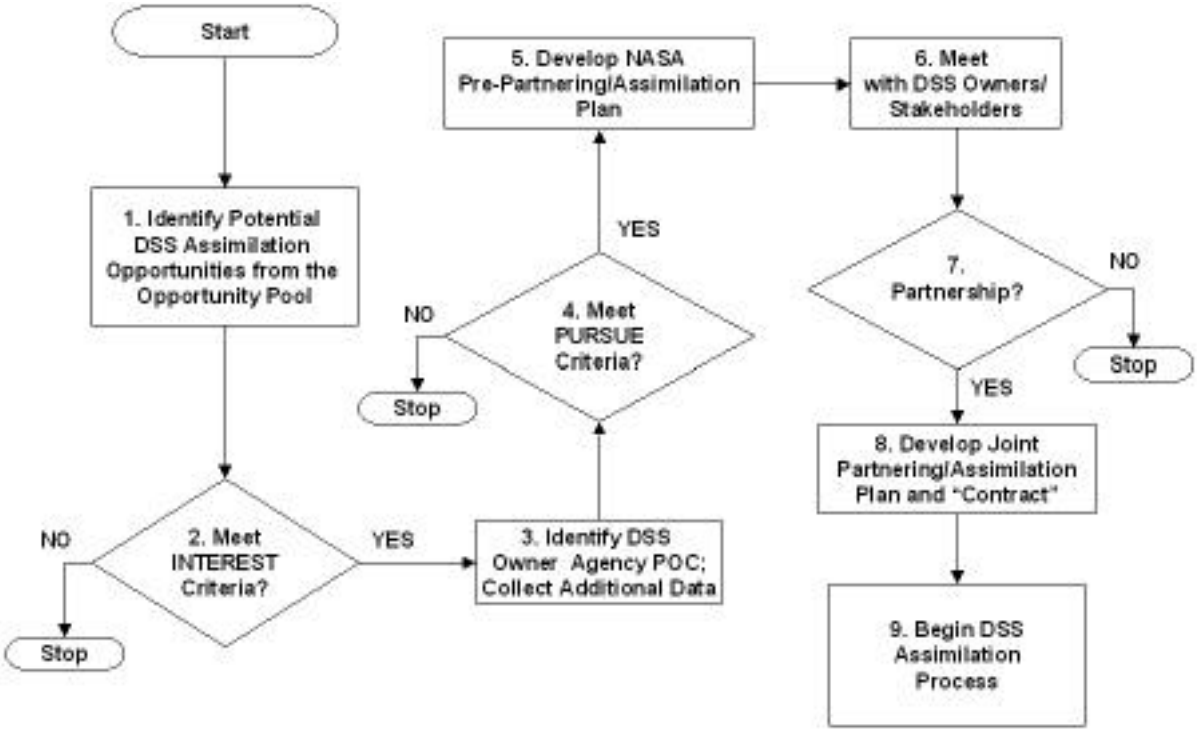


Figure 10. DSS selection process.

[2] This model is based on experience in business development at Northrop Grumman and LTV

The cognizant Application Program Manager will form the NASA AT. Multiple teams may be formed, but the teams should all operate under the guidelines outlined in this process to ensure consistency of output. The composition of this team will cover the spectrum of required technical, business, analytical, and interpersonal skills necessary for success. The team will be accountable for its success. It is important to note that success in one form might be a successful partnership agreement, while in another form success might be a decision not to pursue a particular DSS. This selection process embodies an approach to planning and analysis that will reveal these alternatives.

Table 2. Initial proposed DSS Interest Criteria.

Interest Criteria
Fit DSS/DST definition
Opportunity for partnership
DSS Characteristics Current State (planning/prototype, operational, mature) Mission, Goals, Objectives (clear) Operational concept (feasible) Required outputs (known and related to mission, goals, objectives) Program plan (achievable)
Appropriate for NASA Compatible with NASA Mission Fits NASA investment portfolio National applications-related
NASA technology meets DSS requirements (DSS enhancement potential) (Includes ARL – see section 5.1.3 below) NASA has science, data, technology and/or models that match DSS output requirements NASA application maturity/readiness levels meet DSS timelines
Cost of Participation to NASA Time Dollars
Offers Measurable Outcomes
Barriers

The second step in the process is to determine if the DSS opportunity selected fully meets NASA Interest Criteria. A set of Interest Criteria developed based on experience to date is provided in Table 2; a more detailed description of the Interest Criteria is provided in Appendix C. This list will be

reviewed and validated in collaboration with NASA HQ and other Centers during FY2004. These criteria might change over time, but it is essential that NASA apply a consistent set of interest criteria that provide an objective basis for selecting the opportunities with the best chance for success and best returns on NASA investment. Since DSS data and information at the beginning stages of the selection process may be collected and analyzed absent the benefit of contact with an Owner POC, the data will be less detailed than at later stages. However, the opportunity-rich environment still requires a process that can eliminate high-risk low-value endeavors before significant resources are expended.

The first two criteria require only yes or no answers. A yes means continue, a no means stop (hence "Go / No Go"). For example, the system under investigation may meet the DSS definition ("Go") but may not be suitable for a partnership ("No Go). Since only DSSs amenable to partnering for assimilation of NASA observations/predictions are of interest, the system is dropped from further consideration (and resource expenditure). A scoring and weighting scheme is proposed for development in conjunction with NASA HQ and other Centers in FY2004. This step may simply quantify answers, which were arrived at subjectively; however, it ensures that there is a consistent set of criteria to help decide which DSS opportunities to pursue. The remaining criteria should be scored and weighted based on their importance to NASA. Criteria development is an evolutionary process; over time, the list and approach should be refinable and, ultimately, a methodology should be derived to develop such dimensions as minimum scores and weighting factors.

All of the information may not be available early in the process, especially before contact with a DSS POC (Step 3). IT IS, THEREFORE, IMPORTANT TO NOTE THAT THE INTEREST CRITERIA WILL BE REVISTED AND REFINED THROUGHOUT THE SELECTION PROCESS to include the Pursue phase (see below). As implied by this approach, a DSS may at first be of interest but, as information/data are collected and analyzed, this interest-level evaluation may change from positive to negative. The main point is that needed evaluation will be done before a DSS is selected for major attention and investment. This approach is a major improvement to the FY2003 process where, in many cases, selections were made before systematic evaluation was performed.

Having decided that NASA has a valid interest in enhancing a specific DSS, contact with the DSS ownership must be established and a DSS POC must be determined (Step 3). To this point, the DSS has primarily been examined based on open-source materials. Now direct contact and continuous contact with the owner Agency is necessary. NASA and potential partners will discuss their desires and intent and establish points-of-contact to facilitate the transfer of information. The purpose of these steps is to begin building a relationship and gathering of the detailed information needed to make a decision to pursue a particular partnership.

With the help of the DSS owner POC, more in-depth information will be collected and analyzed to decide whether to make major investments in pursuing a specific DSS. *Just as not all opportunities will pass the Interest Criteria test, not all opportunities will pass the Pursue Criteria.* As with the interest decision, a set of Pursue Criteria has been developed for use in the decision process (Step 4) as shown in Table 3. Scoring for the Pursue Criteria will be developed in FY2004. Many of these criteria are very similar to the interest criteria. This process is ongoing and the data/information will be dramatically enriched, especially since they will be based on detailed discussion with DSS owners. As the process is refined the criteria lists might merge, BUT THE NEED FOR BOTH INTEREST AND PURSUE DECISIONS WILL REMAIN CONSTANT.

Having analyzed the DSSs of interest and decided which DSSs are worth pursuing, it may be necessary to further down select to optimize NASA's investment to those DSSs with the best potential payoff. Resource availability will be the governing factor at this juncture.

Table 3. Initial proposed DSS Pursue Criteria.

Pursue Criteria
Fits NASA program (amplifies and refines earlier analyses, re: Appropriateness and program considerations)
Funding/Fiscal feasibility NASA Budget (Code YO) DSS Budget (DSS Owner)
Stakeholders (Who is involved in DSS decisions beyond owners? What are the politics involved?)
NASA capability to meet DSS requirements
Probability of success DSS NASA science, data, technology and/or models for assimilation
NASA ARL meets DSS program plan
Partnering strategy is feasible
Dual-use potential (Is value for the proposed NASA science, data, technology and/or models in more than one DSS?)
Potential socio-economic value

Developing a NASA pre-partnering and assimilation plan is the next step (Step 5). This plan can take a variety of forms, but will commonly be a presentation developed to fuel discussion with potential partners. This plan is essential because it provides the NASA AT with a starting position for the formal partnering phase. This plan should detail NASA's mission, goals, objectives, strategies, and investment; e.g., how NASA believes the partnership could operate and how its observations and predictions could be assimilated. This vision of the partnership's future state will help NASA ensure that both the partner agency and NASA's desired outcomes are realized.

Until this point, contact with the DSS owner has been informal and has been conducted primarily through the POC. Now the formal process for entering into a partnership and determining how the assimilation process should proceed will begin (Step 6). While it should be rare given the preparation provided by our front-end assessment, it is still conceivable that the owner and/or NASA will decide to stop the venture and not partner (Step 7). Should the partnership proceed, the development of a joint plan and agreement (Step 8) will precede the assimilation process (Step 9).

5.1.3 Application Readiness Level

NASA's desire is to show applicability of its data products to current and future national applications. To facilitate this and to assist with planning and management of projects and investments, NASA must develop a balanced portfolio of DSSs to be evaluated and enhanced. In this context, a balanced portfolio will include DSSs that are easily and immediately enhanced as well as DSSs that will require greater time and/or effort to enhance to ensure both short-term and long-term successes. A significant step in the selection process (as described in Step 3 of Figure 10) is determining the readiness of the DSS to accept NASA input as well as the readiness of NASA products to be assimilated into the DSS. Together, these two readiness states form the Application Readiness Level (ARL). Ultimately, the ARL is an indicator of when an enhanced DSS may be ready to support a given National Application.

While selecting DSSs for assimilation, varying degrees of DSS developmental maturity will be encountered. Five (5) maturity levels or developmental phases can be assigned to a given DSS:

1. Conceptual. During the initial phase, a statement of need or a requirements document is developed.

2. Design. Concepts and requirements from the end user are used to identify data sources, algorithms, constraints, operational environments, budget, and other parameters that will dictate the development of the DSS. At this stage, alternatives to these parameters can still be introduced.

3. Development. In this phase, the parameters that were identified during the design phase are integrated into a workable DSS.

4. Test/Demonstrate. Ideally, only minor changes should be made during this phase as the DSS is tested and problems are encountered.

5. Operational. At this phase, the DSS is being used operationally. Typically, making changes to a DSS in this phase will be difficult unless the DSS has been engineered in such a way as to accept additional input.

Just as any given DSS has several maturity levels, the NASA products to be assimilated into the DSSs have many Product Readiness Levels (PRLs). These PRLs can be assigned to one of four (4) categories:

A. Not Planned. NASA does not currently plan this class of products. If the product is required, the requirement can be made known to the Earth Science Technology Office for evaluation.

B. Planned. These products do not currently exist but will be available in the future. For example, a dataset that will be provided by a future satellite mission and could be assimilated into the DSS would be "planned."

C. Current but Not Easily Assimilated. These products exist, but the candidate DSS cannot readily accommodate the format, resolution, constraints, or some other parameter associated with the product.

D. Current and Easily Assimilated. These products currently exist and can be easily assimilated into the candidate DSS. For this to be the case with an operational DSS, the DSS would have been engineered to accommodate additional or alternative input, which is not necessarily true in most cases.

For example, a given DSS's developmental stage may fall anywhere between conceptual and operational. Similarly, appropriate NASA products and models may or may not exist and may or may not be readily assimilated into the DSS. None of these conditions is intrinsically good or bad; they just give an indication of how much time, work, risk, and/or money may be required to assimilate NASA products into the DSS.

Table 4 shows the various states of readiness that may be applied to an application. In this two-step process, the DSS is first evaluated for its maturity level. If the DSS is still in a conceptual stage, one may anticipate that it will be 2-6 years (or longer) before the DSS is operational, depending on the complexity of the DSS. However, if the DSS were in a further stage of development, one would expect a shorter wait for operational readiness. In the second step, the NASA products to be assimilated are evaluated. If those products already exists and can be readily assimilated into the DSS, an enhanced DSS may be available in a few months. But if the technology is planned for the future or has to be developed, a corresponding delay to achieve an enhanced operational capability is inevitable.

For example, if a DSS is operational, NASA products are available to enhance the DSS, and those products are readily integrated into the DSS, the application readiness level would be 5D. At the opposite end of the scale, if the DSS is in a conceptual stage and no applicable NASA products exist or are planned, the application readiness level would be 1A. Of course, most DSS/PRL combinations would fall somewhere between those two extremes. The indicated time frames in Table 4 (e.g., 1-3 years for ARL 3C) are STRICTLY NOTIONAL. It could be that a given ARL fits the 3B criteria, but because of anticipated complexities, an enhanced DSS is not expected to be available for at least 5 years. Similarly, it may be possible for a given 1D ARL to be operational with NASA enhancements in 2 years or less.

Table 4. DSS maturity and NASA product assimilation matrix with notional time frames.

	NASA Product Readiness for Assimilation

		A. Not Planned	B. Planned	C. Current; Not Easily Assimilated	D. Current; Easily Assimilated
DSS Maturity Level	1. Conceptual	>6 Years	3-6 Years	3-6 Years	3-6 Years
	2. Design	>6 Years	3-6 Years	3-6 Years	1-3 Years
	3. Development	>6 Years	3-6 Years	1-3 Years	0-1 Years
	4. Test/Demonstrate	>6 Years	3-6 Years	1-3 Years	0-1 Years
	5. Operational	>6 Years	1-3 Years	1-3 Years	0-1 Years

Each combination of parameters yields a different path for NASA product and model enhancement to the DSS—some of those paths being short and easy, and some being long and complex. Generally, as the ARL designation moves from 1A to 5D, time, risk, cost, and effort can be expected to decrease. Of course, increasing cost, risk, and/or effort may shorten the time factor. If one defines the ARL as the time it takes for all the pieces to come together resulting in an enhanced DSS, the ARLs can be summarized as immediate, short-term, mid-term, or long-term, as shown in Table 5.

Table 5. Application readiness levels summary.

Application Readiness Level	Time to Realize Enhancement
Immediate	0-1 Years
Short Term	1-3 Years
Mid Term	3-6 Years
Long Term	>6 Years

NASA's balanced portfolio will have a strategic mix of each category, generating a continuous flow of NASA-derived enhancements. Some DSS enhancements may yield immediate or short-term, low-cost, low-risk, operationally oriented results. Such enhancements will be balanced with enhancements that require more effort, higher risk, and visionary planning.

5.2 Evaluation, Verification & Validation, and Benchmarking Processes

A modified systems engineering approach (Figure 11) for the assimilation of NASA data into DSSs allows NASA to quantify the impact that ESE data products and models have on the partner-owned DSSs. The approach starts with three steps of the DSS selection process described in Section 5.1:

(1) initialization from a pool of DSS opportunities cataloged as one-page DSS summaries, (2) first-look assessments of the DSSs and identification of possible NASA inputs from observations and predictions, and (3) a meeting between NASA and potential partner organization to explore the concept of the partnership. The selection activities are dominated by NASA actions, but they cannot be concluded without participation of the partner organization, as discussed in section 5.1.2.

After the decision to form a partnership is accepted and formalized, a joint team from NASA and the partner organization begins establishing baseline status of the selected DSS and defining requirements and specifications for the enhanced DSS. This work is focused on developing technical requirements of the DSS and on understanding NASA's ability to meet the DSS needs. When NASA's existing ability does not meet the DSS needs, an application-specific NRA (NASA Research Announcement) may be released to solicit solutions to meet the needs. These potential solutions will represent one of the alternatives that NASA will investigate. When these tasks are completed, NASA proceeds with design and implementation of a prototype for the DSS enhancements. This task is accompanied by verification & validation and benchmarking of the prototype and allows for investigation of alternative solutions to the DSS enhancement problem. The processes of V&V and benchmarking used during this phase are the same as those described in section 2.4. The prototypical design and implementation of the DSS enhancements will be continually and iteratively refined according to the systems engineering principles (note feedback loops in the "Investigate Alternatives" box in Figure 11).

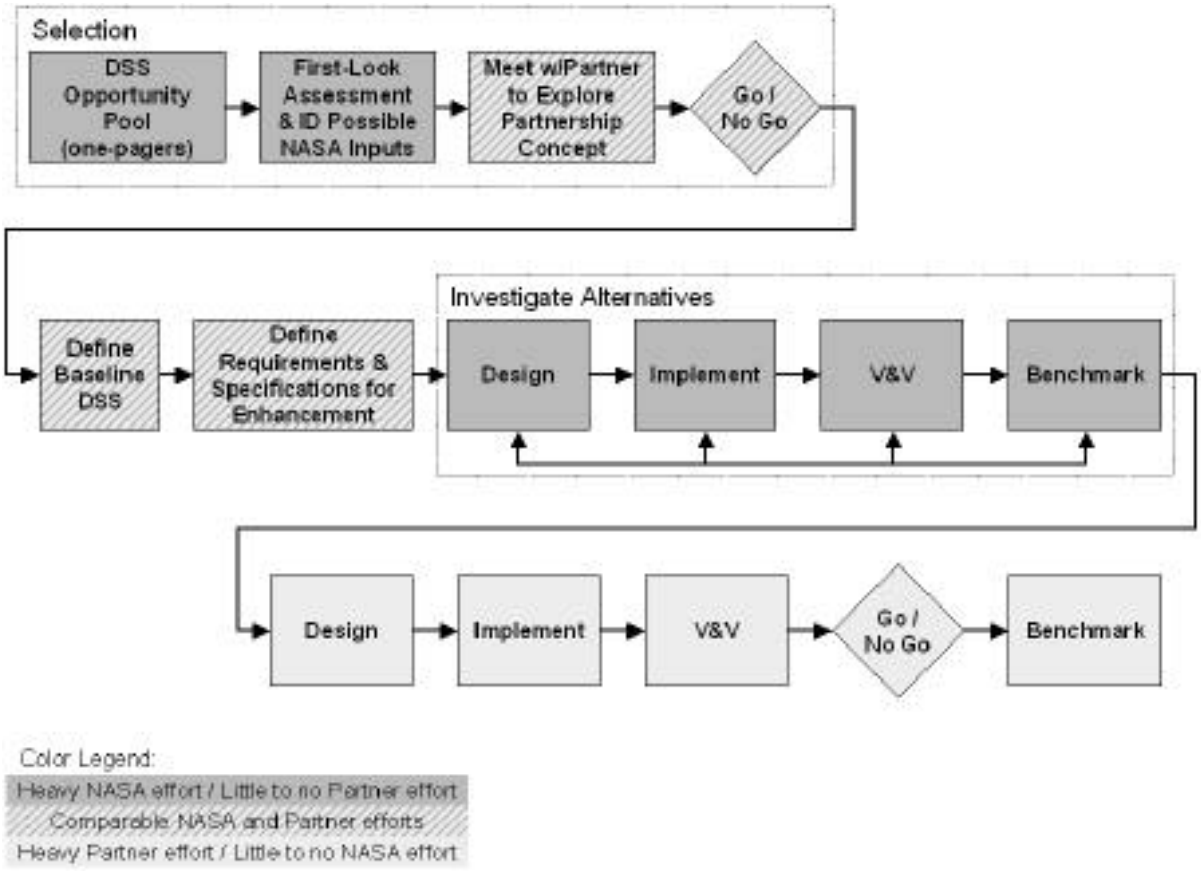


Figure 11. Modified systems engineering approach.

After reviewing results of NASA benchmarking of the DSS enhancements, the partner organization proceeds with assimilation of NASA data products into the partner's operational environment. The partner organization follows its own process for design, implementation, V&V, and benchmarking of the enhanced DSS. The last step of that process, benchmarking, is optional and can be omitted when the partner organization fully accepts the NASA benchmarking.

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Appendix A. Glossary

Benchmark – A standard by which a product can be measured or judged (i.e., How did the DSS that assimilated NASA measurements compare in its operation, function, and performance to the earlier version?). The benchmarking process is required to support adoption of innovative solutions into operational environments that affect life and property.

Decision Support System (DSS) – a computer based information-processing system for scenario optimization through multi-parametric analysis. A DSS utilizes a knowledge base of information with a problem solving strategy that may routinely assimilate measurements and/or model predictions in support of the decision making process. The DSS provides an interface to facilitate human inputs and to convey outputs. Outputs from a DSS would typically be used for making decisions at the local level and outputs from multiple DSSs may be used in establishing policy.

Decision Support Tool (DST) – a suite of solutions owned by NASA partners that are used in a variety of problem domains for decision and policymaking. These solutions could include assessments, decision support systems, decision support calendars, etc.

Evaluation – Identify decision support tools (assessments and DSSs) that have been developed by Federal agencies and other partners that are a priority to citizens of our nation and that can be enhanced by NASA ESE results. Develop the specifications for how the candidate DSS can be augmented by assimilating NASA ESE observations and predictions.

Verification – A life cycle process to ensure the products being developed meet the stated specifications (functional, performance, and design).

Validation – A process to ensure the completed products (software, algorithm, model) effectively serve the functional requirements.

Appendix B. List of Acronyms and Abbreviations

Arbonet	Arbovirus Surveillance Network
ARL	Application Readiness Level
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AT	Assimilation Team
AVHRR	Advanced Very High Resolution Radiometer
AWARDS	Agricultural Water Resources Decision Support
AWIN	Aviation Weather Information Network
AWIPS	Advanced Weather Interactive Processing System
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
CADRE	Crop Assessment Data Retrieval and Evaluation *a.k.a.* Crop Condition Data Retrieval and Evaluation
cal/val	calibration and validation
CMAQ	Community Multi-scale Air Quality modeling system
Code YO	ESE Applications Division at NASA HQ
DAAC	Distributed Active Archive Center
DDP	Defect Detection and Prevention (Kaupp et al., 2003)
DMS	Decision Making System (Kaupp et al., 2003)
DSS	Decision Support System
DST	Decision Support Tool
EA92	Energy Act of 1992
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPHTN	Environmental Public Health Tracking Network
ESA	Earth Science Applications Directorate
ESE	Earth Science Enterprise
ESTO	Earth Science Technology Office
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper plus
FAS	Foreign Agriculture Service
FEMA	Federal Emergency Management Agency
FY2003	Fiscal Year 2003
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellite
GNOME	General NOAA Oil Modeling Environment
GSD	Ground Sample Distance
HAB	Harmful Algal Bloom
HABMapS	HAB Mapping System
HAZUS	Hazards U.S.
HAZUS-MH	HAZUS Multi-Hazard

HDF	Hierarchical Data Format
HDF-EOS	HDF-EOS
HQ	Headquarters
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
ISFS	Invasive Species Forecasting System
ISPRS	International Society for Photogrammetry and Remote Sensing
Landsat	Land Remote-Sensing Satellite
LDCM	Landsat Data Continuity Mission
MMS	Malaria Modeling and Surveillance
MODIS	Moderate Resolution Imaging Spectroradiometer
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRCan	Natural Resources Canada
PAGIS	Protected Area Geographic Information System
PECAD	Production Estimates and Crop Assessment Division
PM2.5	Particulate Matter less than 2.5 micrometer in diameter
POC	Point of Contact
POES	Polar Operational Environmental Satellite
REASoN	Research, Education, and Applications Solutions Network
RETScreen	Renewable Energy Technology Project Analysis Software
RiverWare	River Basin Modeling Software
SAFESEAS	System on AWIPS for Forecasting and Evaluation of Seas and Lakes
SSC	Stennis Space Center
SPOT	Satellite Pour l'Observation de la Terre
SVS	Synthetic Vision System
SWAMP	Spatial Wetland Assessment for Management and Planning
TM	Thematic Mapper
TRMM	Tropical Rainfall Measuring Mission
TVA	Tennessee Valley Authority
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
V&V	Verification and Validation

Appendix C. DSS Criteria Considerations

C.1. INTEREST

This Appendix provides amplification concerning the use of the Interest Criteria outlined at Section 5.1.2 in this report. Its purpose is to present a framework for a consistent approach to compare the relative value of DSSs and, thereby, facilitate decisions regarding which DSS presents the best partnering opportunity. This framework is intended to be flexible and adaptable, not rigid in its application.

Criteria	**Considerations (NOTE: *It is very important to be consistent in applying the criteria in order to compare DSSs equally.*)**
1. Fit DSS / DST definition	This is a "Go / No Go" consideration. Unless NASA's guidance directs otherwise, projects that do not fit the NASA DSS definition should be dropped from further consideration at the earliest possible time in the process.
2. Opportunity for partnership	Considering DSS ownership and stakeholders is another "Go / No Go" proposition. If the likelihood of partnering is low, the opportunity should be dropped before significant resources are invested.
3. DSS Characteristics	
· Current State	Consider the state of the candidate DSS in terms of its lifecycle based on the ARLs discussed in Section 5.1.3: Conceptual; Design; Build; Test/Demonstrate; Operational. Based on the assumption that assimilation is easier in earlier stages, preference should be placed on DSSs that are early in the life cycle
· Missions/Goals	Consider the available DSS planning documentation. Is there a complete plan in place? Are milestones in place? Is there a stated mission? Are goals well defined and achievable? Are objectives measurable? Is there a set of improvements that are needed/desired? Essentially, determine if there is a complete plan in place to help assess NASA's risk threshold.
· Operational Concept	This characteristic considers how the DSS will work in its intended operational environment. Will it meet operational requirements? Does the intended user community embrace the need? Does the intended use fit NASA's mission and goals?
· Required Outputs	This consideration establishes the basis for NASA investment in the DSS. The key question: Are the required DSS outputs such that assimilation of NASA science, data, technology and/or models into the DSS will add measurable value and be cost effective?

· Program plan	The major program considerations are funding and milestones. Key questions include: Is there a DSS program plan in place that includes funding? Is the program plan timeline/milestone schedule such that the NASA inputs to be assimilated will be available?
4. Appropriate for NASA	
· Compatible with NASA mission	The compatibility of the DSS and its intended mission, purpose, etc. with NASA's mission, goals and objectives is an important consideration. In order to assess compatibility, it is important to pose questions such as: Will NASA investment in this DSS expand and accelerate the realization of societal and economic benefits from NASA Earth science, information and technology? Will this investment likely yield measurable benefits from NASA's Earth Science investments?
· Fits NASA investment portfolio	This is a consideration that deals with feasibility. It is a weighted factor. If NASA has not planned for investments of the size required to partner with and enhance the DSS it should not be a high priority target to pursue.
· National Applications related	The first part of this consideration borders on "Go / No Go". If the DSS does not show potential for one of the 12 National Applications, it may well be rejected. The question is: Does the DSS show significant promise in resolving key issues identified in the National Applications considered.
5. NASA technology meets DSS requirements	
· NASA has science, data, technology and/or models that match DSS output requirements	This consideration relates to requirements of the DSS. Would the current planned state of the DSS in terms of meeting its requirements be enhanced by assimilation of NASA science, data, technology and/or models, and to what degree?
· NASA application maturity/readiness levels meet DSS timelines	This consideration ensures that the NASA ARL (Section 5.1.3) and DSS timelines are compatible.
6. Cost of participation to NASA	
· Time	One cost consideration is time. Enhancing a DSS that requires a shorter time investment may be preferable to a DSS enhancement that will require a longer time commitment. NASA may simply not want its scarce resources tied up for extended periods of time.

· Dollars	Dollars are the driver. It may simply be too expensive to participate regardless of the attractiveness of the DSS. This is especially true in the case of unforeseen opportunities that aren't budgeted. Cost considerations include: manpower, equipment, facilities and support activities such as travel and per diem. Best estimates must be made and used in comparing alternative opportunities.
7. Offers Measurable Outcomes	The ability to quantify the result of assimilating a NASA input into a specific DSS is an important consideration. How much will users benefit from the DSS enhancement? Is there measurable socio-economic benefit? This consideration is grounded in being able to baseline (determine State 1 as defined by Kaupp et al., 2003) the DSS before assimilation and benchmarking the resultant enhancements to determine success (State 2, Kaupp et al., 2003). Considerations include: manpower savings, value stream mapping, enhanced decision quality information, improved response times, etc. The specific considerations will differ between DSSs.
8. Barriers (Hayden, 1986)	Consideration must be given to the amount of resistance that may be encountered as we try to develop partnerships. Interest may not be present at all levels and to the same degree. Current owners and stakeholders may prefer the system as it is. Generally, the more mature the system, the higher the entry barrier because changing project direction is often expensive, hence a cost barrier. Similarly, the DSS may be politically sensitive or the partner agency's policies may present barriers and challenges. This consideration is linked to questions of non-technical feasibility.

C.2. PURSUE

In addition to continuing to enrich the data/information available regarding the INTEREST CRITERIA, above, the following criteria help resolve issues related to selecting DSSs most suitable for assimilation of NASA science, data and/or technology.

Criteria	**Considerations (NOTE: *It is very important to be consistent in applying the criteria in order to compare DSSs equally.*)**
Fits NASA program (amplifies and refines earlier analyses, re: appropriateness and program	Data/information regarding this criterion will be collected and analyzed throughout the process. As in any partnership, both parties should benefit. This criterion

considerations)	ensures a focus on direct benefits to a NASA Program.
Funding/Fiscal feasibility	
· NASA Budget (Code YO)	If we obligate to a partnership, we should be sure the Agency can follow-through on fiscal and other resource commitments or cease efforts to pursue the activity.
· DSS Budget (DSS Owner)	It is necessary to ensure potential partners have the budget to contribute to a mutually beneficial DSS/DST collaboration.
Stakeholders (who is involved in DSS decisions beyond owners? What are the politics involved?)	DSS end-user stakeholders should be considered. Stakeholders include State and Federal political supporters, federal agency advocates, etc. Non-owner stakeholders may be the final decision makers, and NASA should be aware of their identity and intentions before a large investment is made.
NASA capability to meet DSS requirements	Early and frequent consideration must be given to the ability of a NASA input to add significant value at an appropriate time in the DSS development cycle.
Probability of success	
· DSS	Will the DSS be successful without a NASA contribution? How much will a NASA contribution enhance/enrich DSS success?
· NASA science, data, technology and/or models for assimilation	Considering the probability of NASA science, data, technology and/or models being successful sooner in the assimilation process rather than later is essential to save resources. It may be relatively simple to think of ways NASA might upgrade DSS outputs. The real question is: Can we prove that the assimilation will be successful before committing significant NASA resources?
NASA ARL meets DSS program plan	This consideration is designed to constantly evaluate NASA's ability to meet DSS timelines. It ensures that the NASA ARL and DSS timelines are compatible.
Partnering strategy is feasible	Constant monitoring of the partnership agreement is necessary to be sure that the interests of both NASA and the partner agency are being met by the joint collaboration.
Dual-use potential	Consider if the proposed NASA science, data, technology and/or models have value for more than one DSS.
Potential socio-economic value	What will be the benefit to the taxpayer? How will the life of the average citizen be enhanced? What are the potential benefits to the US economy? The considerations in this domain are myriad.

Appendix D. One-page DSS Summaries

Decision Support Systems

One-page summaries

General Comment

Potential NASA Inputs list ESE mission instruments that, after a cursory look by SSC systems engineering personnel, showed potential for providing data/products beneficial to a given DSS: Further investigation and requirements definition are still needed.

Earth Science Enterprise: Applications

Applications Mission:

Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology

12 National Applications


Carbon Management


Public Health

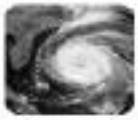

Energy Management


Aviation


Water Management


Homeland Security


Coastal Management


Disaster Management


Agricultural Efficiency


Invasive Species


Ecological Forecasting


Air Quality

Environmental Public Health Tracking Network (EPHTN)

EPHTN is a tracking system that integrates data about environmental hazards and exposures with data about diseases that are possibly linked to the environment. EPHTN allows decision makers to monitor and distribute information about environmental hazards and disease trends and implement and evaluate regulatory and public health actions to prevent or control environment-related diseases.

- **National Application: Public Health**
- **Owner Agency: Center for Disease Control and Prevention (CDC).**
  National Center for Environmental Health (NCEH)
- Website: http://www.cdc.gov/nceh/divisions/ehhe.htm
- Operational Status: Estimated 2005-2007
- Use of NASA data:
  - Potential:
    - Terra / Aqua MODIS
    - Landsat
    - TRMM
    - TOMS
    - SAGE III
    - UARS
    - SOURCE

Community Multi-Scale Air Quality Modeling System (CMAQ)

CMAQ models multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. CMAQ is designed to have multi-scale capabilities so that separate models are not needed for urban and regional scale air quality modeling.

- **National Application: Air Quality**
- **Owner Agency: Environmental Protection Agency (EPA)**
- Supporting Organization: Atmospheric Modeling Division
- POC: Kenneth L. Schere, CMAQ Program Manager, Environmental Protection Agency, E243-03, USEPA Mailroom, Research Triangle Park, NC 27711, Tel.: 919-541-3795, schere.kenneth@epa.gov
- Website: http://www.epa.gov/asmdnerl/models3/cmaq.html
- Operational Status: 1991
- Potential use of NASA data:
  - Airborne: HIS, LASE, NAST-1, RASL, S-HIS, MATR
  - Aqua AIRS
  - Aqua AMSR-E
  - Aqua AMSU
  - Aqua HSB
  - Aura OMI
  - Aura TES
  - CALIPSO
  - CloudSat
  - Earth Probe / TOMS
  - EO3 / GIFTS
  - ESSP-3 / OCO
  - Meteor-3M / SAGE III
  - TOPEX / Poseidon
  - Terra / Aqua MODIS
  - Terra MOPITT

Hazards U.S. (HAZUS)

HAZUS® is a natural hazard loss estimation methodology implemented through PC-based Geographic Information System (GIS) software. HAZUS was first developed to assess the effects of earthquakes but is now being expanded to include models to address flooding (riverine and coastal) and wind (hurricanes, thunderstorms, tornadoes, tropical cyclones and hail) hazards (multi-hazard methodology: HAZUS-MH).

- **National Application: Disaster Preparedness**
- **Owner Agency: Federal Emergency Management Agency (FEMA)**
- Supporting Organization: National Institute of Building Sciences
- POC: Claire Drury, FEMA, (202) 646-2884, hazus@fema.gov
- Website: http://www.fema.gov/hazus/
- Operational Status:
  - HAZUS available since 1997
  - HAZUS-MH planned for 2003
- Use of NASA data:
  - Current: via USGS
  - Potential:
    - SRTM
    - Landsat 7
    - Terra ASTER
    - Terra / Aqua MODIS
    - Terra MISR
    - QuikSCAT SeaWinds
    - TRMM
    - Wind modeling

RETScreen & Surface Meteorology and Solar Energy Applications Project (SSE)

NASA Langley Research Center's Surface Meteorology & Solar Energy Applications Project (SSE) works with NRCan's CANMET Energy Diversification Laboratory (CEDRL) to provide global radiation budget datasets. SSE is crucial to the success of the emerging renewable market providing accurate, global solar radiation and meteorology data.

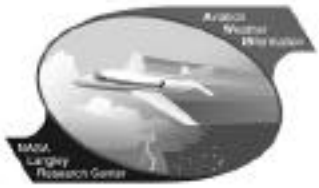
- **National Application: Energy Forecasting**
- **Owner Agency: Natural Resources Canada (NRCan)**
- POC: Gregory J. Lend, Section Head, Natural Resources Canada, 1615 Lionel-Boulet Blvd., Varennes, Quebec J3X1S6
- Website: http://www.retscreen.net/
- Operational Status: 1998
- Use of NASA data:
  - Current: -
  - Potential:
    - TRMM / Terra / Aqua CERES
    - Aqua / ADEOS II AMSR
    - Earth Probe TOMS
    - CloudSat
    - CALIPSO
    - GIFTS
    - SeaWinds

RETScreen™ Renewable Energy Project Analysis Software

Aviation Weather Information (AWIN)

AWIN provides improved weather information to users in the National Airspace System and fosters the improved use of this information. AWIN emphasizes providing information to the flight deck while considering other weather information users in the National Airspace.

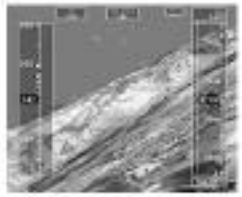
- **National Application: Aviation Safety**
- **Owner Agency: Federal Aviation Administration (FAA)**
- Supporting Organization: NASA Aviation Safety Program (AvSP), Weather Accident Prevention (WxAP)
- POC: Paul Stough, Crew/Vehicle Integration Branch, NASA Langley Research Center, Hampton, VA 23681-2199, 757-864-3860, h.p.stough@larc.nasa.gov
- Website: http://awin.larc.nasa.gov/
- Operational Status: 2000
- Use of NASA data:
  - Potential:
    - TRMM
    - Terra / Aqua CERES
    - GIFTS



Synthetic Vision Systems (SVS)

The aircraft SVS concept is designed to provide increased safety and operational benefits in normal and low visibility conditions. SVS displays provide better pilot situation awareness and improve aviation safety.

- **National Application: Aviation Safety**
- **Owner Agency: NASA**
- Website: http://avsp.larc.nasa.gov/images_svs.html
- Operational Status :
  - Feasible commercial systems available in 2006 to 2008
- Use of NASA data:
  - Potential:
    - SRTM
    - Landsat 7
    - Terra ASTER



Agricultural Water Resources and Decision Support (AWARDS)

AWARDS improves the efficiency of water management and irrigation scheduling by providing guidance on when and where to deliver water and how much to apply. The ET Toolbox extension of AWARDS is able to provide water use inputs for RiverWare which supports water management decisions.

- **National Application: Water Management**
- **Owner Agency: U.S. Bureau of Reclamation**
- POC: Curt Hartzell, *Meteorologist*, River Systems & Meteorology Group, 303 445 2482, chartzell@do.usbr.gov
- Website: http://www.usbr.gov/rsmg/nexrad
- Operational Status : 2000
- Use of NASA data:
  - Current:
  - Potential:
    - Terra / Aqua MODIS
    - Landsat 7
    - Terra ASTER
    - SRTM
    - TRMM
    - GPM

Bureau of Reclamation
Managing Water in the American West

RiverWare

RiverWare is a flexible general river basin modeling tool that allows water resources engineers to simulate and optimize the management of multipurpose reservoir systems. RiverWare automatically generates and efficiently solves a multi-objective, pre-emptive, linear goal programming formulation of a reservoir system.

- **National Application: Water Management**
- **Owner Agency: University of Colorado, Center for Advanced Decision Support for Water and Environmental Systems (CADSWES)**
- Supporting Organization: U.S. Bureau of Reclamation, Tennessee Valley Authority
- POC: Terry Fulp, *Manager*, USBR River Systems & Meteorology Group, Denver, CO, 303 445 2470, dmatthews@do.usbr.gov
- Website: http://cadswes.colorado.edu/riverware/
- Operational Status : 2000
- Use of NASA data:
  - Potential:
    - ERBS SAGE II
    - Terra / Aqua / TRMM
    - Terra / Aqua CERES
    - TRMM
    - GPM

Harmful Algal Bloom Mapping System and Bulletin (HABMapS)

The HAB bulletin provides timely information to the management community in the Gulf of Mexico during a bloom event. The HAB Mapping System (HABMapS) is an interactive mapping tool that can be used to access recent data on harmful algal blooms in the Gulf of Mexico and on the environmental conditions that may affect the spread of these blooms.

- **National Application: Coastal Management**
- **Owner Agency: NOAA CoastWatch and Coastal Services Center**
- POC: Mary Culver, Coastal Services Center, National Oceanic and Atmospheric Administration, Charleston, SC, 843 740 1250, Mary.Culver@noaa.gov
- Website: http://www.csc.noaa.gov/crs/habf/
- Operational Status : 2000
- Use of NASA data:
  - Current:
    - SeaWiFS, QuikSCAT SeaWinds
  - Potential:
    - Terra / Aqua MODIS
    - Aqua AIRS
    - ADEOS II SeaWinds
    - JASON-1
    - TOPEX / Poseidon
    - Landsat 7 ETM+
    - Terra ASTER
    - SRTM

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

Better Assessment Science Integrating point and Nonpoint Sources (BASINS)

BASINS is a multipurpose environmental analysis software for use by regional, state, and local agencies in performing watershed and water quality based studies. It allows users to assess water quality at selected stream sites or throughout an entire watershed.

- **National Application: Water Management**
- **Owner Agency: Environmental Protection Agency (EPA)**
- POC: Dr. Russell Kinarson, EPA, (202) 566-0409, basins@epa.gov
- Website: http://www.epa.gov/waterscience/basins/
- Operational Status: Available since 1996
- Use of NASA data:
  - Potential:
    - SRTM
    - Terra ASTER
    - Landsat 7 ETM+
    - Terra / Aqua MODIS
    - QuikSCAT
    - TOPEX / Poseidon
    - Jason
    - TRMM
    - GPM
    - GRACE

Crop Condition Data Retrieval and Evaluation (CADRE)

CADRE is a geospatial database management system used for assessment of global crop conditions and estimates of area, yield, and production for grains, oilseeds, and cotton.

- **National Application: Agricultural Efficiency**
- **Owner Agency: U.S. Department of Agriculture (USDA), Production Estimates and Crop Assessment Division (PECAD)**
- Supporting Organization: Foreign Agriculture Service (FAS)
- POC: Brad Doorn, PECAD, (202) 690-0131, pecad@fas.usda.gov
- Website: http://www.fas.usda.gov/pecad/
- Operational Status: in use since early 1980s
- Use of NASA data:
  - Current:
    - Landsat 5 & 7
  - Potential:
    - Terra / Aqua MODIS
    - TRMM
    - SRTM
    - Aqua / ADEOS II AMSR
    - HYDROS
    - Terra / Aqua CERES
    - Landsat
    - Terra ASTER
    - TOPEX / Poseidon

Cutting-Edge Software to Cut Emissions in support of 1605(b)

The EPA's emissions reduction software in support of Department of Energy's Voluntary Greenhouse Gas Reporting Program [established by section 1605(b) of the Energy Policy Act of 1992] offer regional/local decision makers tools for managing waste, emissions, and energy consumption. These decision support tools include Waste Reduction model (WARM), Cities for Climate protection (CCP) and MSW Decision Support Tool (DST).

- **National Application: Carbon Management**
- **Owner Agency: US EPA**
- Supporting Organization: Unknown
- Website:
  http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/MCOD5K5P85/$File/softwaretools.pdf
- Operational Status: Current
- Use of NASA data:
  - Current: None
  - Potential: None

Invasive Species Forecasting System

The National Invasive Species Forecasting System is designed for the management and control of invasive species on all U.S. Department of Interior and adjacent lands. This project will use early detection and monitoring protocols and predictive models to create on-demand, regional-scale assessments of invasive species patterns and vulnerable habitats.

- **National Application: Invasive Species**
- **Owner Agency: NASA Goddard Space Flight Center, USGS-Biological Resources Division**
- POC: John L. Schnase, Ph.D., Earth and Space Data Computing Division, NASA Goddard Space Flight Center, schnase@gsfc.nasa.gov.
- Website: http://www.usgs.gov or http://biology.usgs.gov/invasive/index.htm
- Operational Status: in use since early 1980s
- Use of NASA data:
  - Current:
  - Potential:
    - SRTM
    - Terra
    - Aqua
    - Landsat
    - SeaWiFS

Application of a Management Decision Aid for Sequestration of Carbon and Nitrogen in Soil

Monitoring the of storage of carbon in soil can serve as a guide to policy makers, scientists and crop producers as 1) a means of increasing storage of carbon in soil, 2) determining the value of stored organic matter, and 3) the most likely cost efficient means of increasing soil carbon.

- **National Application: Carbon Management**
- **Owner Agency: USDA Agricultural Research Service**
- Supporting Organization: Agricultural Research Service (ARL)
- POC: Olness Alan E, ARL **aolness@mail.mrsars.usda.gov**
- Website:
  http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=105299
- Operational Status: Approved September 1999
- Use of NASA data:
  - Potential:
    - Landsat 7
    - Aqua

Century soil organic matter (SOM) model

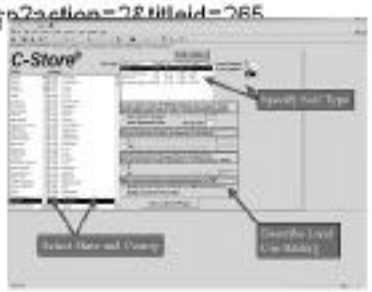
The SOM model ingests variables such as; temperature, precipitation, soil physical characteristics (texture, hydric class, etc.), and land management providing a decision support tool to enable land owners to identify areas most likely to benefit from prairie restoration for both forage production and carbon sequestration.

- **National Application: Carbon Management**
- **Owner Agency: Colorado State University**
- POC: Richard T. Conant, Colorado State University
- Website: http://www.casmgs.colostate.edu/insider/vigview.asp?action=2&titleid=178
- Operational Status: Reconnaissance and data collection began January 2001
- Use of NASA data:
  - Potential:
    - Landsat 7
    - Aqua

CSTORE

CSTORE is designed to quantify and assess soil carbon stock changes in agricultural systems, as a function of different management practices. The model is suitable for estimating soil carbon changes for different management practices and can be used by decision makers to project design, forecasting and quantification for agricultural systems.

- **National Application: Carbon Management**
- **Owner Agency: Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS)**
- Supporting Organization: USDA
- POC: Keith Paustian, Colorado State University
- Website: http://www.casmgs.colostate.edu/insider/vigview.asp?action=2&titleid=265
- Operational Status: Development stage
- Use of NASA data:
  - Potential:
    - Terra
    - Aqua
    - Landsat 7



Carbon Sequestration approaches and modeling tools at AGLL of FAO

The carbon sequestration approaches and modeling tools of AGLL and FAO develop scenarios of land use and land management options for prevention of land degradation and enhancement of land productivity through carbon sequestration and biodiversity conservation.

- **National Application: Carbon Management**
- **Owner Agency: Land and Plant Nutrition Management Service (AGLL)**
- Supporting Organization: Land and Water Development Division, Food and Agriculture Organization of the United Nations (FAO)
- Website: http://www.fao.org/ag/agl/agll/carbonsequestration/docs/carbon.pdf
- Operational Status: 2000 - present
- Use of NASA data:
  - Potential:
    - Terra
    - Aqua
    - Landsat 7

TsunamiReady

StormReady

A TsunamiReady is a National Weather Service (NWS) initiative that promotes tsunami hazard preparedness as an active collaboration among Federal, state and local emergency management agencies, the public, and the NWS tsunami warning system. This collaboration supports better and more consistent tsunami awareness and mitigation efforts among communities at risk.

- **National Application: Community Growth**
- **Owner Agency: National Weather Service**
- Website: http://www.stormready.noaa.gov/tsunamiready.htm
- Operational Status: Established 1949
- Use of NASA data:
  - Current:
  - Potential:
    - SeaWinds
    - TOPEX / Poseidon
    - Jason-1
    - Aerial photography

Coastal Restoration and Enhancement through Science and Technology (CREST)

CREST will work with the network of restoration professionals around the northern Gulf of Mexico, identify key issues of coastal restoration, facilitate the continued advancement of restoration science, and export this new knowledge both to other parts of the United States and further afield.

- **National Application: Coastal Management**
- **Owner Agency: Louisiana State University, Louisiana State University Agricultural Center, Louisiana Universities Marine Consortium, McNeese State University, Nicholls State University, Southeastern Louisiana University, Southern University at New Orleans, Tulane University, University of Louisiana at Lafayette, University of New Orleans, and University of Southern Mississippi.**
- Supporting Organization: National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS).
- POC: Piers Chapman, Director, CREST Office, Louisiana State University, Baton Rouge, LA 70803, 225-578-0069, pchapman@lsu.edu
- Website: www.gulfcrest.org
- Operational Status: 2003
- Use of NASA data:
  - Potential:
    - Aerial photography

CREST Coastal Restoration and Enhancement through Science and Technology

Regional Crop Condition and Yield Assessment

The Regional Crop Condition and Yield Assessment model monitors regional agricultural crop conditions using satellite data. The simulations compare very well with the farmer reported yields at the study sites.

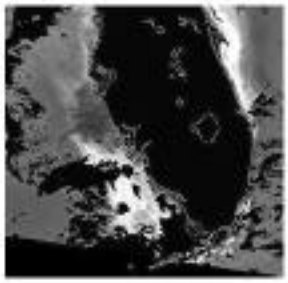
- **National Application: Agricultural Efficiency**
- **Owner Agency: United States Department of Agriculture (USDA)**
- Supporting Organization: National Research Service (ARS)
- POC: Paul Doraiswamy, USDA, (301) 504-6576, pdoraisw@asrr.arsusda.gov
- Website: http://www.nps.ars.usda.gov/projects/projects.htm?accession=403085
- Operational Status:
  - Start Date: Aug 01, 1999
    End Date: Nov 01, 2002
- Use of NASA data:
  - Current:
    - Terra ASTER (land cover)
    - Terra / Aqua MODIS

USDA ars

Red Tide Prediction

The Red Tide Prediction provides detection of algal blooms as they occur offshore, rather than after the bloom has arrived onshore. This allows researchers to alert coastline communities of approaching harmful algal blooms.

- **National Application: Coastal Management**
- **Owner Agency: University of Florida**
- Supporting Organization: College of Marine Science
- POC: Kendall Carder, University of Florida, (727) 553-3952, kcarder@monty.marine.usf.edu
- Website: http://www.marine.usf.edu/
- Operational Status: Submitted proposal April 2003
- Use of NASA data:
  - Potential:
    - Terra / Aqua MODIS (sea surf. temp.)



Hypoxia Watch System for the Gulf of Mexico

The Hypoxia Watch System offers near-real time map products of bottom dissolved oxygen that would form the basis for summertime advisories on anoxic and hypoxic conditions in the North-central Gulf of Mexico and disseminate the data over the Internet.

- **National Application: Coastal Management**
- **Owner Agency: National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS), NOAA National Coastal Data Development Center (NCDDC), National Aeronautics and Space Administration's Earth Science Applications Directorate, Coastal Ecology Institute at Louisiana State University, and the CoastWatch Gulf of Mexico Regional Node.**
- Supporting Organization: Louisiana Universities Marine Consortium (LUMCON)
- POC: Dr. Nancy Rabalais, LUMCOM (985) 851-2836, nrabalais@lumcon.edu
- Website: http://coastwatch.noaa.gov/GOMxhypoxia/
- Operational Status: NOAA Bottom Dissolved Oxygen Maps and related data available June 5, 2002
- Use of NASA data:
  - Current: via NOAA
  - Potential: Terra / Aqua MODIS (sea surf. temp.)

NESDIS CoastWatch Program

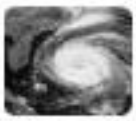
NOAA's CoastWatch program processes raw satellite data produce imagery that will help meteorologists predict weather, fishermen locate fish, and scientists track oil spills and red tide events.

- **National Application: Coastal Management**
- **Owner Agency: National Oceanic and Atmospheric Administration (NOAA)**
- Supporting Organization: National Environmental Satellite Data and Information Service (NESDIS)
- POC: Christopher Brown, NOAA, (301) 740-5803, Christopher.W.Brown@noaa.gov
- Website: http://sgiot2.wwb.noaa.gov/COASTWATCH/
- Operational Status: Currently available
- Use of NASA data:
  - Current: via NOAA

Multiple Use Management of the EEZ (Exclusive Economic Zone)

Multiple Use Management of the EEZ (Exclusive Economic Zone) is a study to provide a model to help strengthen management in key regions of Australia's Exclusive Economic Zone.

- **National Application: Coastal Management**
- **Owner Agency: Commonwealth Scientific & Industrial Research Organisation (CSIRO)**
- Supporting Organization: Marine Research
- POC: John Parslow, CSIRO, 61-36-232-5202, John.Parslow@marine.csiro.au
- Website: http://www.marine.csiro.au/research.html\Operational
- Operational Status: Unknown
- Use of NASA data:
  - Potential:
    - Terra / Aqua MODIS (sea surf. temp.)



MODIS Land Rapid Response System

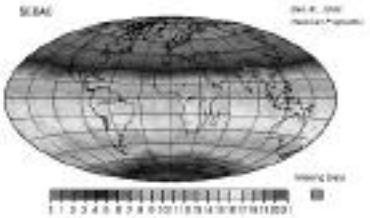
The MODIS Land Rapid Response system produces a daily active fire detection product from its data feed in near-real time (~4 hours from acquisition). These data are being provided to the US Forest Service (USFS) and other partners through the Global Observation of Forest Cover (GOFC) project for application to fire management and refinement/validation of the product.

- **National Application: Disaster Preparedness**
- **Owner Agency: Global Observation of Forest Cover**
- Supporting Organization: US Forest Service
- POC: Ron Sohlberg, University of Maryland, (301) 405-4292, rsohlber@geog.umd.edu
- Website: http://rapidresponse.umd.edu
- Operational Status: Current
- Use of NASA data:
  - Current: via USFS

Near-Real Time Global UV Dose Map Generation

Near-Real Time Global UV Dose Map Generation provides daily integrated estimates of clear sky erythema-effective UV dose amounts and peak UV Index estimates.

- **National Application: Public Health**
- **Owner Agency: SEDAC**
- Supporting Organization: CIESIN Columbia University, http://www.ciesin.org/
- Website: http://sedac.ciesin.org/ozone/maps/eptpage.html
- Operational Status: 1997 - 2000
- Use of NASA data:
  - Current:
    - ADEOS
    - Earth Probe (EP)



UltraViolet Interactive Service (UVIS)

UVIS provides a centralized directory from which users may access available sources of data related to human health effects of ultraviolet radiation exposure. This portion of the Stratospheric Ozone and Human Health project provides on-screen visualization of hourly, daily, and monthly-averaged ultraviolet radiation dose quantities and corresponding total column ozone values.

- **National Application: Public Health**
- **Owner Agency: SEDAC**
- Supporting Organization: CIESIN Columbia University, http://www.ciesin.org/
- Website: http://sedac.ciesin.columbia.edu/ozone/docs/uvd-home.html
- Operational Status: 1979-1990
- Use of NASA data:
  - Current: historical data only
  - Potential:
    - TOMS

UVI US Map

The NOAA/EPA UV Index Map uses various datasets to produce a forecast of the ozone data for the next day. This map represents UV intensities at solar noon / approximate noon local standard time or 1.00 pm local daylight time. With this information decision makers can post warnings about potentially dangerous UV levels.

- **National Application: Public Health**
- **Owner Agency: National Oceanic and Atmospheric Administration (NOAA)**
- Supporting Organization: Environmental Protection Agency (EPA)
- Website: http://www.safesun.com/uv_map.html
- Operational Status: Current
- Use of NASA data:
  - Potential:
    - Earth Probe (EP)

Soil analysis using TRMM satellite

Accumulated seasonal data of global soil moisture reveals the movement of heat, which tells the mechanism of climate changes, and therefore makes the prediction of such changes possible. While such observations of soil moisture had been conducted regionally before, this project was the first to succeed in global monitoring of soil moisture using a satellite.

- **National Application(s): Energy Forecasting, Disaster Preparedness, Agriculture Efficiency**
- **Owner Agency: NASDA**
- Supporting Organization: Institute of Industrial Science, University of Tokyo
- Website: http://spaceboy.nasda.go.jp/note/eisei/e/eis0010_trmm_e.html
- Operational Status: 1997 – Current (?)
- Use of NASA data:
  - Potential:
    - TRMM (Precipitation Radar)

The Earth Simulator

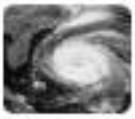
The mission of the Earth Simulator is to build a harmonious relationship between the Earth and human beings. The Earth Simulator integrates super computing hardware, physical models for global change prediction, and satellite data into one coherent project. Through collaboration with various national-related agencies and industries and with the support of the Japanese nation, the Earth Simulator Project is dedicated to serving society.

- **National Application(s): Energy Forecasting, Disaster Preparedness, Agriculture Efficiency**
- **Owner Agency: NASDA**
- Supporting Organization: NASA, Scripps Institution of Oceanography Hadley Center for Climate Prediction and Research , CIRA (Italian Aerospace Research Center)
- POC: E. Eng., Keiji Tani, Japan Atomic Energy Research Institute, 81-3-3435-2821, tanik@fusion.naka.jaeri.go.jp
- Website: http://www.es.jamstec.go.jp/esc/eng/ESC/index.html
- Operational Status: May, 2002 - Current
- Use of NASA data:
  - Current: TRMM

The Global Water Cycle Decision-Support Product Testing

The Global Water Cycle Decision-Support Product Testing has substantially reduced uncertainty in tropical precipitation estimates from about 50 percent to about 20 percent. Variations in the water cycle lead to variations in the productivity of many sectors including hydropower production, coastal fisheries, agriculture, and forestry, to name just a few. Better monitoring and prediction of water cycle variations will allow for better management of these resources.

- **National Application: Energy Forecasting, Water Management**
- **Owner Agency: US Global Change Research Program (USGCRP)**
- Supporting Organization: US Dept. of Agriculture, US Dept. of Commerce, Natl. Oceanic & Atmospheric Admin, US Dept. of Defense, US Dept. of Energy, US Dept. of Health and Human Services, National Institutes of Health, US Dept. of the Interior, US Geological Survey, Environmental Protection Agency, NASA, National Science Foundation, Smithsonian Institution
- POC: US Global Change Research Program, Suite 250, 1717 Pennsylvania Ave, NW, Washington, DC 20006, 202 223 6262
- Website: http://www.usgcrp.gov/usgcrp/ProgramElements/recent/waterrecent.htm
- Operational Status: FY 2003 research and observations
- Use of NASA data:
  - Current: TRMM



REMSAD

The Regional Modeling System for Aerosols and Deposition (REMSAD) is designed to support a better understanding of the distributions, sources, and removal processes relevant to fine particles and other airborne pollutants, including soluble acidic components and toxics. REMSAD began as a simple screening tool and evolved into a more complex modeling system that attempts to simulate the chemistry, transport, and deposition of airborne pollutants using algorithms that reflect the state-of-the-science and current knowledge of the important physical and chemical processes.

- **National Application: Disaster Preparedness**
- **Owner Agency:** U.S., Systems Applications International, Inc. (SAI)
- Website: http://www.remsad.com
- Operational Status:
- Use of NASA data:
  - Current:
  - Potential:

State Implementation Plans (SIP)

The State Implementation Plan (SIP) is the cumulative record of all air pollution strategies, statutes, rules, and ordinances implemented under Title I of the Clean Air Act by governmental agencies within the State. The SIP focuses on regulation of the "criteria" pollutants: carbon monoxide (CO), sulfur dioxide (SO_2), ozone (O_3), nitrogen oxides (NOx), lead (Pb), and particulate matter less than 10 microns (PM10). Not all SIPs are the same; however, all of them must be approved by the Environmental Protection Agency (EPA) before they can officially be used as law.

- **National Application(s): Community Growth, Air Quality Management**
- **Owner Agency: Environmental Protection Agency (EPA)**
- Supporting Organization: State Agencies
- POC: Exclusive to Region
- Website: http://www.epa.gov/ebtpages/airairpostateimplementationplans.html, also region specific pages
- Operational Status:
  - SIPs have been in place since 1972
- Use of NASA data:
  - Potential:
    - MOPITT
    - TOMS

Arbovirus Network (ArboNet)

ArboNet is an arboviral surveillance network developed to track a variety of vector-borne Arboviruses.

- **National Application: Public Health**
- **Owner Agency: Center for Disease Control and Prevention (CDC),** National Center for Infectious Diseases (NCID)
- POC: Daniel O'Leary, Division of Vector-Borne Infectious Diseases (DVBID), CDC NCID, Fort Collins, Colorado, dvbid@cdc.gov
- Website: http://www.cdc.gov/ncidod/
- Operational Status: Current

Malaria Monitoring and Surveillance (MMS)

MMS is a multidisciplinary, international collaborative effort to combat malaria and filariasis in the Greater Mekong Subregion using remote sensing and other technologies.

- **National Application: Public Health**
- **Owner Agency:**
  - Armed Forces Research Institute of Medical Sciences (AFRIMS)
  - Mahidol University, Bangkok, Thailand
- POC: Dr. Richard Kiang, NASA Goddard Space Flight Center, richard.kiang@gsfc.nasa.gov
- Website: http://healthyplanet.gsfc.nasa.gov/project3.html
- Operational Status: in development
- Use of NASA data:
  - Potential:
    - Landsat 7

Air Quality Index (AQI) Forecasting

The Air Quality Index (AQI) is a tool for reporting concentrations of the five main pollutants (ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide) to the general public. Methods for forecasting the AQI for particulate matter are being developed and standardized by air pollution control agencies.

- **National Application: Air Quality**
- **Owner Agency: Environmental Protection Agency (EPA)**
- Supporting Organization: National Oceanic and Atmospheric Administration (NOAA)
- POC: Doreen Neil, NASA, (757) 864-8171, Doreen.O.Neil@nasa.gov
- Website: http://www.epa.gov/airnow/index.html
- Operational Status: Estimated October 2003
- Potential use of NASA data:
  - Airborne / HIS; LASE; NAST-1; RASL; S-HIS; MATR
  - Aqua / AIRS
  - Aqua / AMSR-E
  - Aqua / AMSU
  - Aqua / HSB
  - Aura / OMI
  - Aura / TES
  - CALIPSO
  - CloudSAT
  - Earth Probe / TOMS
  - EO3 / GIFTS
  - ESSP-3 / OCO
  - Meteor-3M / SAGE III
  - Poseidon / TOPEX
  - Terra / Aqua MODIS
  - Terra / MOPITT

ReefBase
Decision Support System

ReefBase is an online information system on coral reefs, and was designed to provide relevant data and information to reef managers and scientists, as well as the general public.

- **National Application: Coastal Management**
- **Owner Agency: World Fish Center**
- Supporting Organization: Global Coral Reef Monitoring Network, International Coral Reef Initiative, International Coral Reef Information Network, NOAA's Coral Health and Monitoring Program
- POC: Dr. Jamie Oliver, World Fish Center, ReefBase Project, Penang, Malaysia reefbase@cgiar.org
- Website: http://www.reefbase.org/
- Operational Status: Current
- Use of NASA data:
  - Current: aerial photographs, SeaWiFS and Space Shuttle photos
  - Potential: MODIS, Landsat, Hyperion, ALI,

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

General NOAA Oil Modeling Environment (GNOME)

GNOME is a free computer program downloadable from the Internet that predicts how wind, current, river flow, and tidal processes might spread an oil spill across water over a specified period of time. To use GNOME, describe a spill scenario by entering information into the program; GNOME then creates and displays an oil spill "movie" showing the predicted trajectory of the oil spilled in the scenario.

- **National Application: Coastal Management**
- **Owner Agency: NOAA, Hazardous Materials Response Division (HAZMAT)**
- POC: NOAA HAZMAT at ORR.GNOME@noaa.gov or at 206-526-6317
- Website: http://response.restoration.noaa.gov/software/gnome/gnome.html
- Operational Status: Current
- Use of NASA data:
  - Current:
  - Potential: Landsat 7 ETM, SeaWinds, MODIS, SeaWiFS

SAFESEAS

SAFESEAS is an AWIPS decision assistance tool which continuously monitors marine and adjacent overland conditions for specific marine weather hazards. It automatically alerts the forecasters whenever such conditions are detected. SAFESEAS provides capabilities to display observed marine threats in ways that help forecasters focus on what they consider most important. Thus SAFESEAS helps forecasters make faster, earlier, and higher quality decisions regarding marine watches and warnings.

- **National Application: Coastal Management**
- **Owner Agency: NOAA, National Weather Service, Office of Science and Technology, Meteorological Development Laboratory**
- Website: www.nws.noaa.gov/mdl/safeseas/
- Operational Status: Current
- Use of NASA data:
  - Current: -
  - Potential: -

PAGIS

The Protected Area Geographic Information System (PAGIS) provides spatial data management and Internet capabilities at all National Estuarine Research Reserves (NERR) and National Marine Sanctuaries (NMS).

- **National Application: Coastal Management**
- **Owner Agency: NOAA/NOS, Office of Ocean and Coastal Resource Management's National Marine Sanctuary Division, National Estuarine Research Reserve Division, the Special Projects Office, and the Coastal Services Center**
- Supporting Organization: University of South Carolina Belle W. Baruch Institute for Marine Biology and Coastal Research, ESRI
- POC: Charles Alexander, NOAA's National Marine Sanctuaries, 1305 East-West Highway, Silver Spring, MD 20910, (301) 713-3125
- Website: http://www.csc.noaa.gov/pagis/
- Operational Status: Current
- Use of NASA data:
  - Current:
  - Potential:
    - AVIRIS
    - CRIS
    - Atlas
    - Landsat

Spatial Wetland Assessment for Management and Planning (SWAMP)

SWAMP is a conceptual GIS-based model to help managers prioritize wetland habitats within a watershed. This model consists of two modules, tidal and riverine, that examine a wetland's contribution to water quality, hydrology and habitat.

- **National Application: Coastal Management**
- **Owner Agency: NOAA Coastal Services Center**
- POC: Lori Sutter, NOAA Coastal Services Center, 2234 South Hobson Avenue Charleston, South Carolina 29405
- Website: http://www.csc.noaa.gov/lcr/text/swamp.html
- Operational Status: Current
- Use of NASA data:
  - Current:
  - Potential:
    - Landsat 7 ETM+
    - EO-1 ALI / Hyperion
    - Terra ASTER
    - Terra / Aqua MODIS

Coastal Reef Early Warning System (CREWS)

The CREWS program is designed to collect real time environmental data from prime coral reef sites throughout the world, analyze patterns and trends via expert systems (an artificial intelligence technology) and predict the effects of environmental events on coral reefs such as bleaching, fish and invertebrate spawning and migration.

- **National Application: Coastal Management**
- **Owner Agency: NOAA/AOML**
- POC: Jim Hendee, NOAA/AOML, Coral Health and Monitoring Program, Miami, FL 33149-1026
- Website: http://www.coral.noaa.gov/crw/process.shtml
- Operational Status: Current
- Use of NASA data:
  - Current:
    - QuikSCAT
    - MODIS

National Airspace System (**NAS**)

The NAS Architecture is a blueprint for modernizing the NAS and improving NAS services and capabilities through the year 2015. The architecture's intent is to provide increased benefits to all users while increasing safety through new technologies, procedures, airspace changes, and collaboration among users and providers.

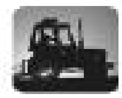
- **National Application: Aviation Safety**
- **Owner Agency: Federal Aviation Administration (FAA)**
- Supporting Organization:
- Website: http://www1.faa.gov/nasarchitecture/
- Operational Status: Phase 2 (2003 - 2007)
- Use of NASA data:
  - Current:
  - Potential:

FEDERAL AVIATION ADMINISTRATION

ASD

Appendix E. First-look Evaluation Results

Agricultural Efficiency



CADRE
Crop Condition Data Retrieval and Evaluation

from:
Foreign Agriculture Service (FAS)
and
Production Estimates and Crops Assessment Division (PECAD)

"First Look" Evaluation

DRAFT 1

FAS and PECAD

The Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture (USDA) works to improve foreign market access for U.S. products. FAS operates programs designed to build new markets and improve the competitive position of U.S. agriculture in the global marketplace.

The Production Estimates and Crop Assessment Division (PECAD) of USDA's Foreign Agricultural Service is responsible for global crop condition assessments and estimates of area, yield, and production for grains, oilseeds, and cotton. ***The primary mission of PECAD is to target, collect, analyze, and disseminate timely, objective, useful, and cost-effective global crop condition and agricultural production information.***

FAS and PECAD

FAS Regions :

- Argentina, Uruguay, Paraguay, Chile
- Brazil
- Mexico, Central America, Caribbean
- Canada, Western Europe
- Central Europe, North Africa
- Turkey, Middle East, Southwest Asia
- Russia, Ukraine, Other Former Soviet Union
- China, Koreas, Japan, South East Asia
- Australia, Bangladesh, India, Pakistan
- Central and Southern Africa
- United States

FAS and PECAD

Once a month, the US Foreign Agricultural Service and experts from the Economic Research Service are 'locked up' in one room to develop an estimate of worldwide agricultural production and yield. During lock-up the group may be organized in as many as five (5) committees based on the commodity (i.e. wheat).

Twelve analysts on staff participate in the lock-up to determine the monthly production estimates by the 8th of each month. Convergence of Evidence

CADRE Basic Facts

CADRE is the operational 'refinement' of the LACIE (Large Area Crop Inventory Experiment) and AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) programs which began in 1974 and 1980, respectively. The models listed below are used in conjunction with internal algorithms and CADRE extraction routines to produce the final outputs.

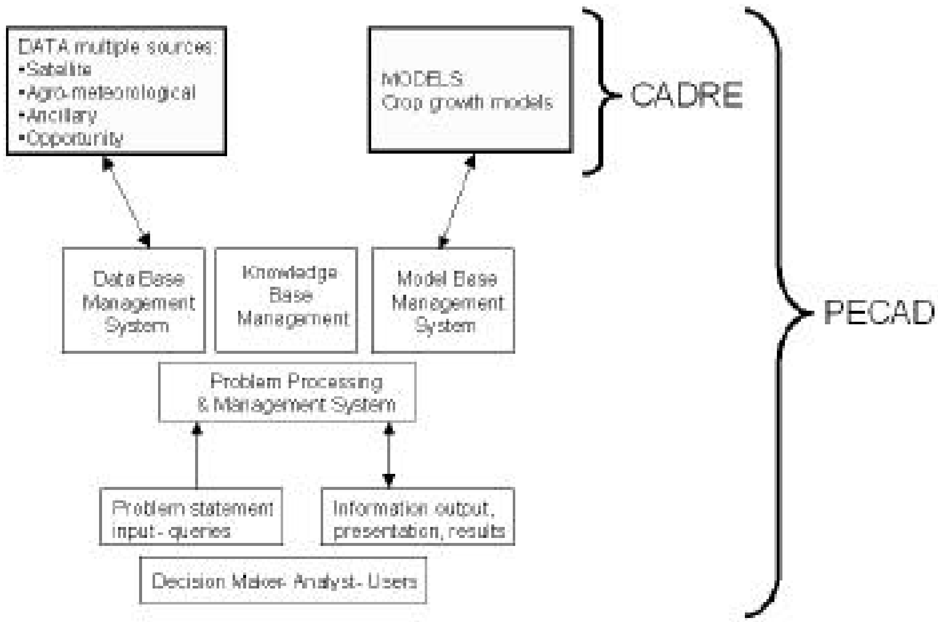
Meteorology:
•AGRMET

Soil:
•FAOSOIL/DSMW
•AgRISTARS

Crop Stress Models (Parameters):
•AgRISTARS

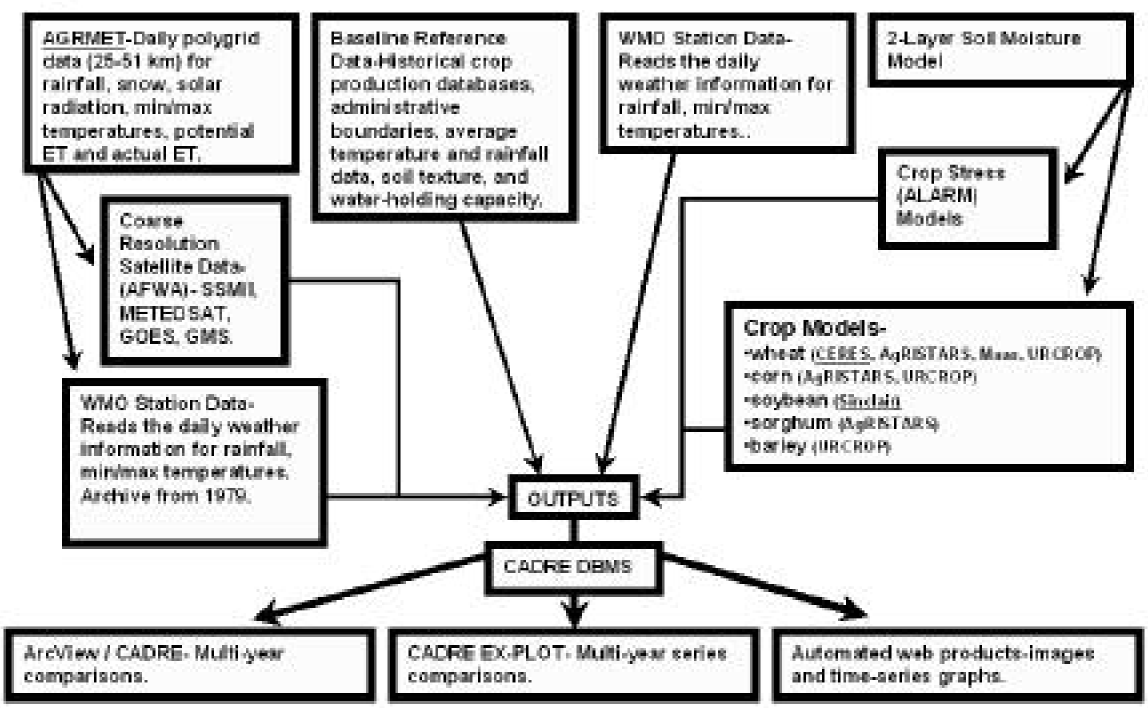
Crop Models:
- Sinclair (soybean)
- CERES (wheat)
- AgRISTARS (wheat, corn, sorghum)
- URCROP (wheat, corn, barley)
- Maas

DSS Sub-systems



(From 'Characterization of PECAD's DSS: a zeroth-order assessment and benchmarking preparation', Hutchinson et. al, 2003)

CADRE Flow Diagram



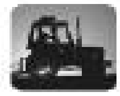
CADRE Inputs

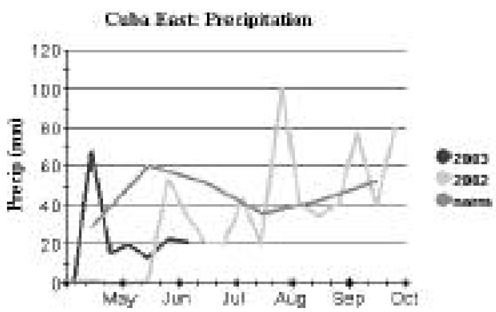
- Minimum and maximum temperature
- Precipitation
- Snow depth
- Solar and long-wave radiation
- Potential and actual evapotranspiration
- Decadal and biweekly vegetation index numbers
- Elevation values
- Soil-water holding capacity

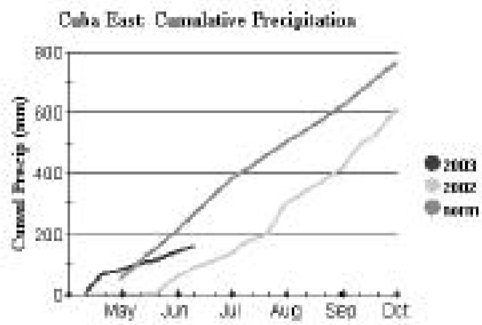
CADRE Outputs

- Spatial images for
  - Estimated precipitation and temperature
  - Actual and cumulative precipitation
  - Average, minimum and maximum temperatures
  - Precipitation and temperature comparisons to long-term norms
  - Temperature departure from normal
  - Percent of normal precipitation
  - Snow depth
  - Top- and sub-layer soil moisture
  - Percent soil moisture in both soil layers
  - Normalized Difference Vegetation Index (NDVI) image anomalies for most major agricultural regions in the world
- Crop calendars
- Crop stress and alarms
- Automated maps and graphs (Crop Explorer)

Crop Explorer Output







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USDA-FAS-PECAD

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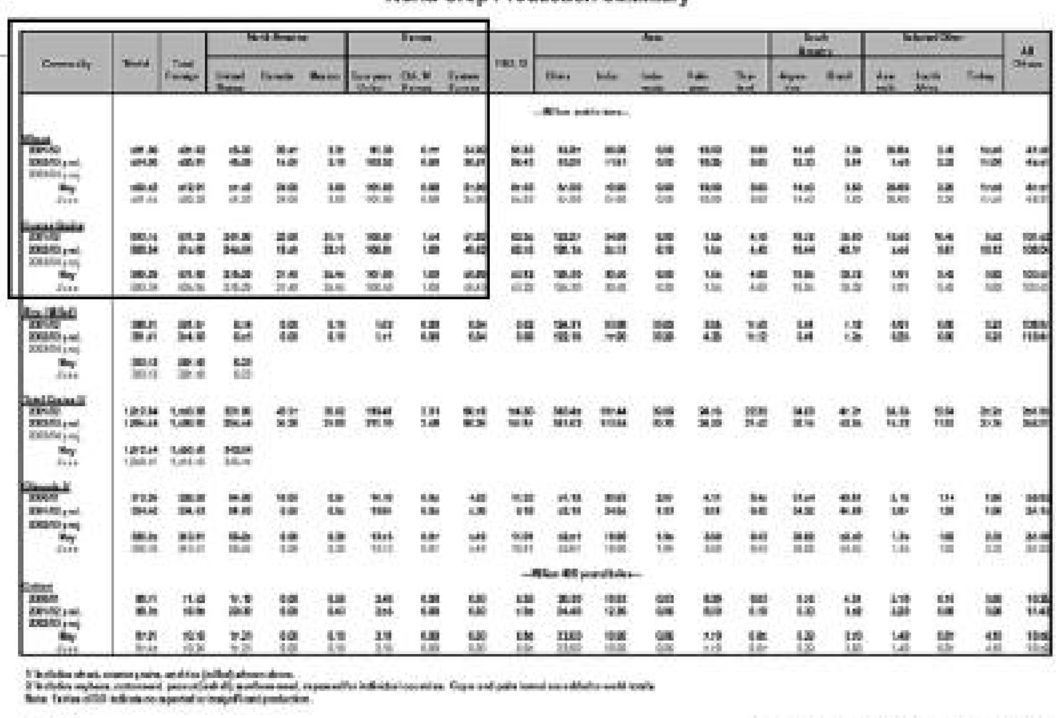


TABLE 1

World Crop Production Summary

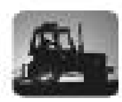
June 2003

As

A…

Commodity	World	Total Foreign	North America			Europe		
			United States	Canada	Mexico	European Union	Oth. W. Europe	Eastern Europe
						-Million Metric Tons-		
Wheat								
2001/02	561.06	527.82	53.26	20.57	3.27	91.20	0.77	34.92
2002/03 prel.	564.00	520.01	43.99	15.69	3.18	103.32	0.89	30.61
2003/04 proj.								
May	569.52	512.01	57.52	24.00	3.00	101.00	0.88	27.99
June	561.45	502.22	59.23	24.00	3.00	101.00	0.88	25.80
Coarse Grains								
2001/02	893.16	631.29	261.86	22.60	27.17	106.67	1.64	51.82
2002/03 prel.	860.04	615.00	245.04	19.59	23.72	106.07	1.69	49.62
2003/04 proj.								
May	909.29	631.00	278.29	27.43	25.45	107.00	1.69	50.86
June	903.34	625.05	278.29	27.43	25.45	106.50	1.69	50.43

Remote Sensing Data Sources



NOAA-14, 15, 16 AVHRR
Landsat 5 and Landsat 7
SPOT VEG
IKONOS
RTNEPH (real time nephanalysis cloud model)
Imager (on GOES)
SSM/I (special sensor microwave/imager on DMSP)
DEM
DOQQ

Potential NASA Data Contributions

- Landsat Data Continuity Mission (LDCM) image products (30-m GSD) (may replace VNIR-SWIR multispectral band data from Landsat 5 TM and Landsat 7 ETM+)
- MODIS land data products (mainly at 1-km GSD, but some at 500-m and 250-m GSD)
  - Snow Cover (MOD10)
  - Land Cover (MOD12)
  - Vegetation Indices (MOD13)
  - Leaf Area Index (MOD15)
  - Evapotranspiration (MOD16)
  - Net Photosynthesis (MOD17)
- TRMM-precipitation and rainfall data
- EO-1 Hyperion-may provide hyperspectral data that can be used in the SSC Applications Research Toolbox (ART) to simulate (by spectral band synthesis) and compare datasets from AVHRR and MODIS

Potential NASA Contributions

- Calculation of area using imagery.
- Change detection.
- Aide and development of spectral library of normal conditions and diseased states.
- Generation of more accurate "past" precipitation estimates.
- .....

CADRE References

- **Websites:**

Crop Explorer

http://151.121.3.218/rssiws/index.cfm

World Agricultural Production OnLine

http://www.fas.usda.gov/wap/current/toc.html

- **Point-of-Contact:**

Brad Doorn
USDA
Foreign Agricultural Service
Production Estimates and Crop
Assessment Division (PECAD)

HAZUS
Decision Support System

"First Look" Evaluation

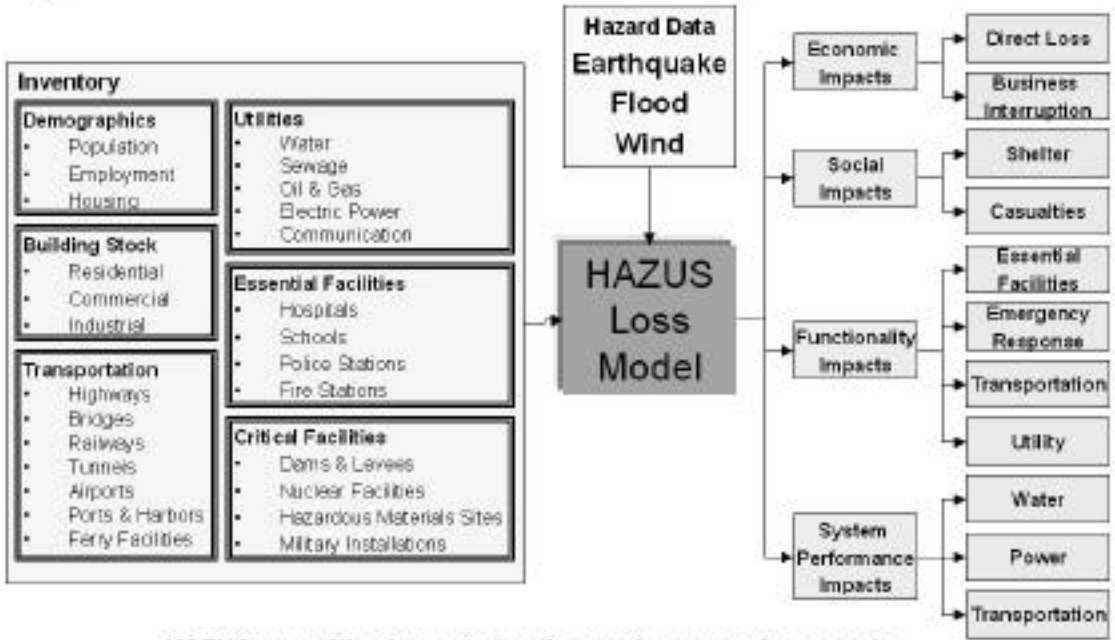
Disaster Preparedness

- As part of its efforts to mitigate hazards and protect lives and property from the devastating effects of natural disasters, Federal Emergency Management Agency (**FEMA**) aims to provide individuals, businesses, and communities with information and tools to work proactively to mitigate hazards and prevent losses resulting from disasters.
- One of these tools is **HAZUS** or *Hazards U.S.*, a natural hazard loss estimation methodology developed by FEMA under contract with the National Institute of Building Sciences (NIBS).
- HAZUS provides decision makers with necessary information to:
  - *IDENTIFY* vulnerable areas that may require planning considerations (e.g., land use or building code requirements)
  - *ASSESS* the level of readiness and preparedness to deal with a disaster before the disaster occurs
  - *ESTIMATE* potential losses from specific hazard events, including pre-event, near real-time, and post-event report capability
  - *DECIDE* on how to allocate resources for the most effective and efficient response and recovery
  - *PRIORITIZE* the mitigation measures that need to be implemented to reduce future losses

HAZUS Basic Facts

- HAZUS is a PC-based software package that allows users to run what-if scenarios.
- HAZUS is currently able to compute estimates of damage and losses that could result from an **earthquake**.
- HAZUS is being expanded into HAZUS-MH, a multi-hazard methodology with new modules for estimating potential losses from **wind** and **flood** hazards.
- HAZUS is implemented through Geographic Information System (GIS) software and is available for East, West, and Central regions of the U.S.
- HAZUS software is provided by FEMA free of charge, but purchase of commercial GIS software is necessary to perform modeling.
- Regularly scheduled HAZUS training classes are held at FEMA's National Emergency Training Center located in Emmitsburg, Maryland, 75 miles north of Washington, D.C.

HAZUS Operational Concept

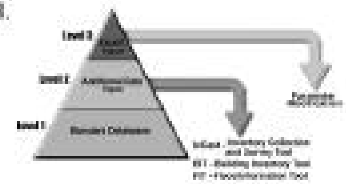


HAZUS quantifies impact of a disaster in terms of economic, social, functionality, and system performance loss estimates.

HAZUS User Levels

HAZUS provides for three levels of analysis:

- **Level 1** analysis yields a rough estimate based on the *Nationwide Databases* of hazards and inventories included in the HAZUS software.
  - This is the best way to begin the risk assessment process and prioritize high-risk communities because all of the needed information is embedded in the software.
- **Level 2** analysis requires the input of additional or refined data and hazard maps that will produce more accurate risk and loss estimates.
  - Assistance from local emergency management personnel, city planners, GIS professionals, and others may be necessary for this level of analysis.
- **Level 3** analysis yields the most accurate estimate of loss and typically requires the involvement of technical experts such as structural and geotechnical engineers who can modify loss parameters based on specific conditions of a community.
  - This level analysis will allow users to supply their own techniques to study special conditions such as dam breaks and tsunamis.
  - Engineering and other expertise is needed at this level.



HAZUS Outputs

HAZUS provides loss estimates for:

- Physical damage
  - Damage to residential and commercial buildings, schools, critical facilities, and infrastructure
- Economic loss
  - Lost jobs, business interruptions, repair and reconstruction costs
- Social impacts
  - Impacts to people, including requirements for shelters and medical aid

	Earthquake Ground Motion Ground Failure	Flood Frequency Depth Discharge Velocity	Hurricanes/Winds Pressure/Missile/Rain
Direct Damage			
General Building Stock	✓	✓	✓
Essential Facilities	✓	✓	✓
High Potential Loss Facilities	✓		
Transportation Facilities	✓	✓	
Lifelines	✓	✓	
Induced Damage			
Fire Following	✓		✓
Hazardous Materials Release	✓		
Debris Generation	✓	✓	
Direct Losses			
Cost of Repairs/Replacement	✓	✓	✓
Income Loss	✓	✓	
Crop Damage		✓	
Casualties	✓		
Shelter and Recovery Needs	✓	✓	
Indirect Losses			
Supply Shortages	✓	✓	
Sales Decline	✓	✓	
Opportunity Costs	✓	✓	
Economic Loss	✓	✓	

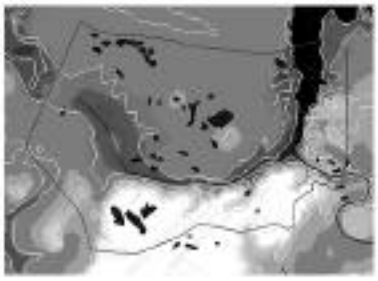
HAZUS Users

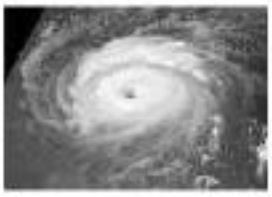
HAZUS has been used since 1997

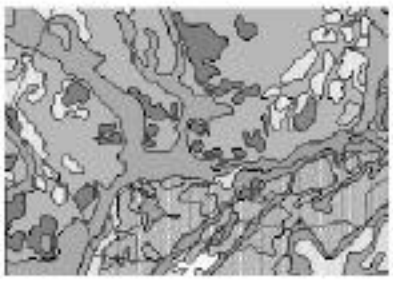
- **Federal, state, and local government officials use HAZUS for pre-disaster preparedness and mitigation and post-disaster planning & response**
  - State of Wyoming – earthquake mitigation for all 23 counties
  - State of CA's Office of Emergency Services – earthquake program
  - South Carolina Emergency Management Division – multiple facets of mitigation planning
  - State of Utah – earthquake risk assessment study
  - Mississippi Emergency Management Agency – earthquake, flood disaster planning
  - Austin, TX – flood studies
  - Pasadena, CA – earthquake and flood areas identified
  - Charlotte, NC and Mecklenburg County, NC – floodplain studies
  - Evansville, IN – risk assessment and mitigation planning
  - Portland, OR – seismic vulnerability of buildings study
  - King-Pierce Counties, WA – Seattle to Tacoma port-to-port corridor earthquake vulnerability study
  - New York City Area Consortium for Earthquake Loss Mitigation – earthquake study by the Multidisciplinary Center for Earthquake Engineering Research
- **Financial institutions such as banks and insurance companies use HAZUS to assess their exposure to the disasters**
  - Charles Schwab, Wells Fargo, Bank of America
- **Universities (professors and graduate students) use HAZUS for advanced applied research**
  - MIT, Georgia Tech, Univ. of Illinois, Princeton Univ., Stanford Univ., UC Berkeley
- **Transportation and utility agencies use HAZUS to assess the reliability of their systems**
  - CA Dept. Trans., L.A. Dept. Water & Power, PG&E

HAZUS Inputs

- Inventories of:
  - Demographics
  - Building stock
  - Critical facilities
  - Transportation
  - Utilities
- Earthquake information
  - Tectonics
  - Soil maps
- Flood information
  - Ground elevations (DEM)
  - Flood elevations
  - Floodplain boundaries
- Hurricane information
  - Sea surface temperature maps
  - Central pressure values
  - "Eye" translation speed
  - Ground surface roughness

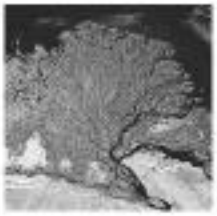


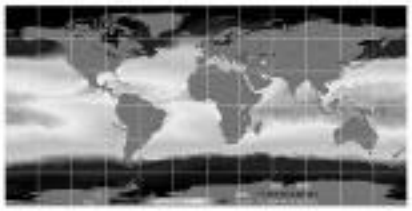




Possible NASA Contributions

- Ground elevation data
  - Shuttle Radar Topography Mission (SRTM)
    - 30-m GSD Digital Elevation Model
  - Posting (ground sampling) distance optimization study
    - LIDAR floodplain mapping project in TX and NC
- Land use data converted to building inventory and soil maps
  - Landsat 7 ETM+
    - 15-m GSD pan-sharpened multispectral images
  - Terra ASTER
    - 15-m GSD multispectral images
- Sea surface temperature
  - Aqua/Terra MODIS
    - 1-km GSD MOD28 data product
- Surface roughness model validation
  - SSC flux tower
    - Wind profile measurements





HAZUS References

- Websites:
  - FEMA: http://www.fema.gov/hazus/
  - NIBS: http://www.nibs.org/hazusweb/
- Point-of-Contact:
  - Claire Drury
    HAZUS Program Manager
    Federal Emergency Management Agency
    500 C Street, S. W.
    Washington, D.C. 20472
    Tel.: 202 646 2884
    Fax: 202 646 2577
    E-mail: hazus@fema.gov

FEMA

AWARDS
Decision Support System

"First Look" Evaluation

Bureau of Reclamation

Managing Water in the American West

Water Management

- Accurate, timely hydrometeorological information is essential for efficient water management.
- Evapotranspiration (ET): the amount of water evaporated from soil and/or transpired by plants. Usually expressed as a depth of water per time period (0.55 mm/hr, 8 mm/day, etc.).
  - It governs the design, planning, and management of irrigation systems and reservoirs around the world.
  - It is a large source of water loss around the globe, so accuracy in estimation is of extreme importance.
- Agricultural water districts can conserve water, and irrigators can improve their operations, when NEXRAD rainfall estimates are coupled with ET models to provide better estimates of water need.

Water Usage Facts

- Largest usage of fresh water is irrigation
  - ~40% of the food worldwide is grown with irrigated land
  - ~60% of the fresh water used by man is used for irrigation (~3 Trillion cubic meters/year)
- 23% of irrigated US farmland is damaged by salt
- Estimated water deficit in US: 14 billion cubic meters/year
  - Worldwide minimum estimate: 164 billion cubic meters/year (~ Half of the US grain harvest)
- 400 million people live in water stressed nations; 3 billion by 2025
- Climate change is a new wild card
  - Decreased snow melts and shorter winters will create larger variability in water supply

AWARDS Basic Facts

AWARDS: Agricultural Water Resources and Decision Support

- Owner: U.S. Bureau of Reclamation
  - Largest wholesale supplier of water in the U.S.; serves more than 31 million people in the 17 contiguous Western States, providing more than 9.3 trillion gallons of water each year.
- Purpose
  - Improve the efficiency of water management and irrigation scheduling by providing guidance on when and where to deliver water, and how much to apply
    - Uses NEXRAD hourly precipitation product
    - 24-hour evapotranspiration product
- Users
  - Reservoir system operators, water district managers / staff, and irrigation organizations use AWARDS system products via the internet to make operational decisions.

ET Toolbox Basic Facts

- ET Toolbox builds on the AWARDS system, adding GIS land use to specify crop, riparian, and open water acreage within each 4 km by 4 km grid cell
  - Accumulates daily rainfall and water use estimates (riparian and crop water use estimates and open water evaporation estimates) within specified river reaches along the Rio Grande.
  - Daily values can serve as input for the *RiverWare* DSS

- Developed by the Bureau of Reclamation for use with the Upper Rio Grande Water Operations Model (URGWOM)
  - URGWOM is a multi-agency effort to develop a numerical computer surface water model that will cover the Rio Grande from its headwaters in Colorado to Fort Quitman, Texas.
  - Over the Middle Rio Grande river reach area, ET from riparian vegetation, irrigated crops, and open water evaporation account for about 60% of the water depletions.

AWARDS Operational Concept

- 1-hour loop
- 24-hour rainfall estimates

NEXRAD Radar Data

Weather Stations Data

24-Hour Data:
- Mean temperature
- Mean relative humidity
- Mean wind speed
- Gage rainfall accumulations
- Total solar radiation

USBR Computers Process Data

NWS Models Rain Forecasts

AWARDS

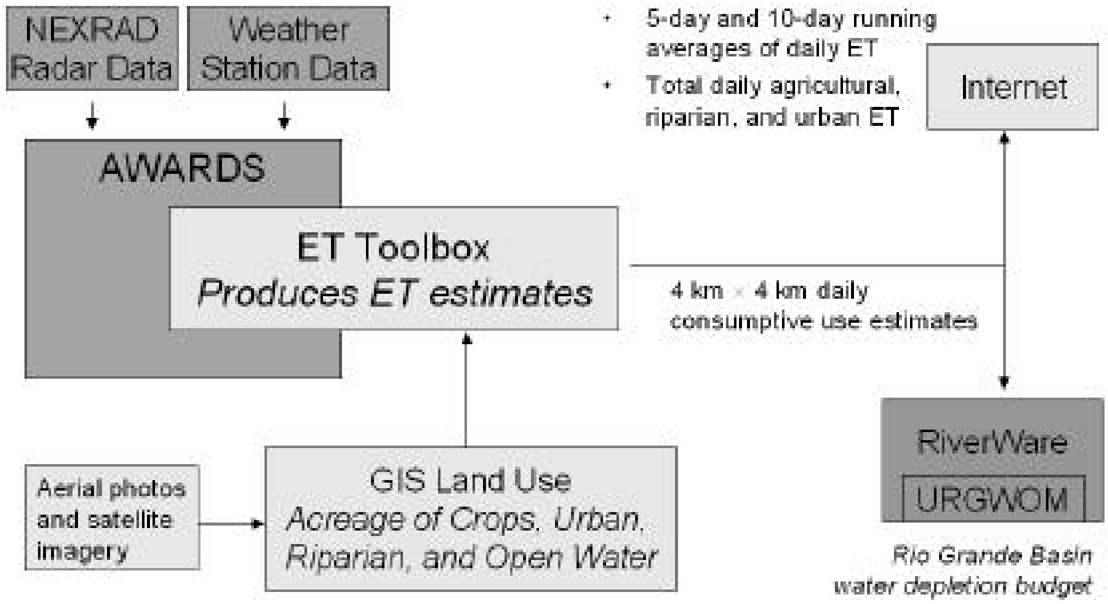
Integrates NEXRAD and weather station data with:
- Crop ET equations
- Local terrain and soil information
- Effective rainfall estimation procedures
- Local daily max/min temp. normals
- Quantitative precipitation forecasts
- Watershed/reservoir systems
- Irrigation water distribution systems

Internet

4 km × 4 km Grid Cell Products:
- NEXRAD rainfall and watershed rainfall water volume estimates
- Effective rainfall estimates
- ET estimates for determining crop water use

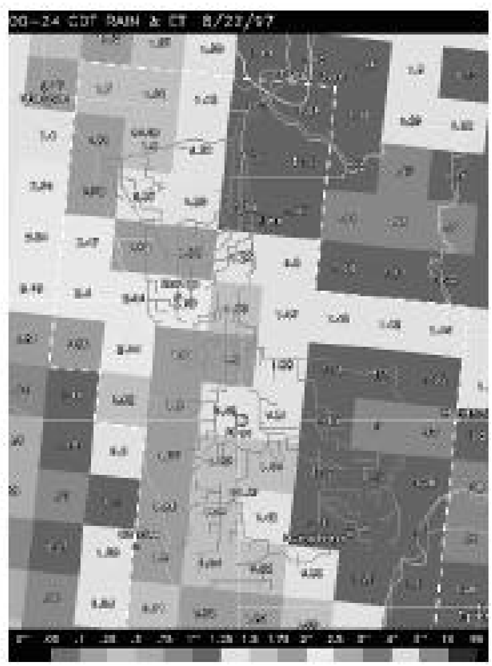
Reservoir Operators, Water Districts, Irrigation Organizations

ET Toolbox Operational Concept



AWARDS Outputs

- NEXRAD radar rainfall and watershed rainfall water volume estimates
- Effective rainfall estimates
- Evapotranspiration estimates for use in determining crop water use requirements
- Improved efficiency of water management and irrigation scheduling



AWARDS Users

- U.S. Department of Interior, Bureau of Reclamation

  Reclamation's water managers in the following regions are still the main users:
  - Upper Rio Grande Basin Projects of Colorado and New Mexico
  - Lower Colorado River Region Projects in AZ, southern CA, NV, and UT
  - Yakima and Upper Columbia Basin Projects in Washington
  - Umatilla Basin Project in Oregon
  - Taulatin Project in northwestern Oregon
  - Rouge River Basin Project in southwestern Oregon
  - Upper Missouri Missoula Valley Region in western Montana
  - South Platte River Basin in northeast Colorado
  - Central Platte River Basin in south central Nebraska
  - Pecos River Basin in eastern New Mexico
  - Lugert-Altus Irrigation District in southwestern Oklahoma

- State and Local Agencies
  - Middle Rio Grande Conservancy District, New Mexico
  - City of Albuquerque, New Mexico
  - Arizona Department of Water Resources
  - Central Arizona Water Conservation District
  - California Department of Water Resources
  - Conejos Water Conservancy District, Colorado
  - Southern Nevada Water Authority

AWARDS Inputs

- Effective rainfall estimates
- Mean temperature
- Mean relative humidity
- Mean wind speed
- Rain gage rainfall accumulations
- Total solar radiation
- Local terrain and soil information
- Local daily max/min temperature normals
- Quantitative precipitation forecasts
- Watershed / reservoir systems
- Irrigation water distribution systems
- Open water evaporation estimates
- Daily riparian and crop water use estimates
- Vegetation imagery
- Land use maps

Possible NASA Contributions

- AWARDS
  - TRMM, GPM, SRTM, MODIS, Landsat 7 ETM+, ASTER
  - GSFC is supplying hydrological models using input from the NRL TRMM Precipitation Product
  - Possible use of TRMM product to fill in NEXRAD gaps associated with mountains and terrain
- ET Toolbox
  - MODIS ET products (MOD16: Evapotranspiration and Surface Resistance)
  - Updated land classification information
    - Landsat 7 ETM+, MODIS, ASTER





AWARDS References

- Website: http://www.usbr.gov/rsmg/nexrad/
- Point-of-Contact:
  - Steven Hunter, *Meteorologist*
    - River Systems & Meteorology Group
    - Tel.: 303 445 2478
    - E-mail: smhunter@do.usbr.gov
  - Tom Pruitt, *Civil Engineer*
    - Ground Water & Drainage Group
    - Tel.: 303 445 2512
    - E-mail: tpruitt@do.usbr.gov
  - Dave Matthews, *Manager*
    - River Systems & Meteorology Group
    - Tel.: 303 445 2470
    - E-mail: dmatthews@do.usbr.gov

  Bureau of Reclamation
  Technical Service Center
  Denver, Colorado

RiverWare
Decision Support System

"First Look" Evaluation

LakeMeadHooverDam

Bureau of Reclamation

Managing Water in the American West

CADSWES

RiverWare Basic Facts

- National Application: Water Management
- Owners: U.S. Bureau of Reclamation (USBR) and the Tennessee Valley Authority (TVA) (1994-1995)
  - Through a cooperative effort between the USBR and the University of Colorado's Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), CADSWES supports, maintains and continually enhances the RiverWare software.
- Purpose
  - Provide software tools for modeling and managing river basins and hydropower systems.
- Hardware Requirements
  - Sun SPARCstation with Solaris 2.7+ operating system
  - Windows NT / 2000 / XP
- Users
  - USBR and TVA – extensive users
  - U.S. Army Corps of Engineers (6 Offices)
  - Numerous state water resources departments, regional water authorities, and several consulting firms

RiverWare Description

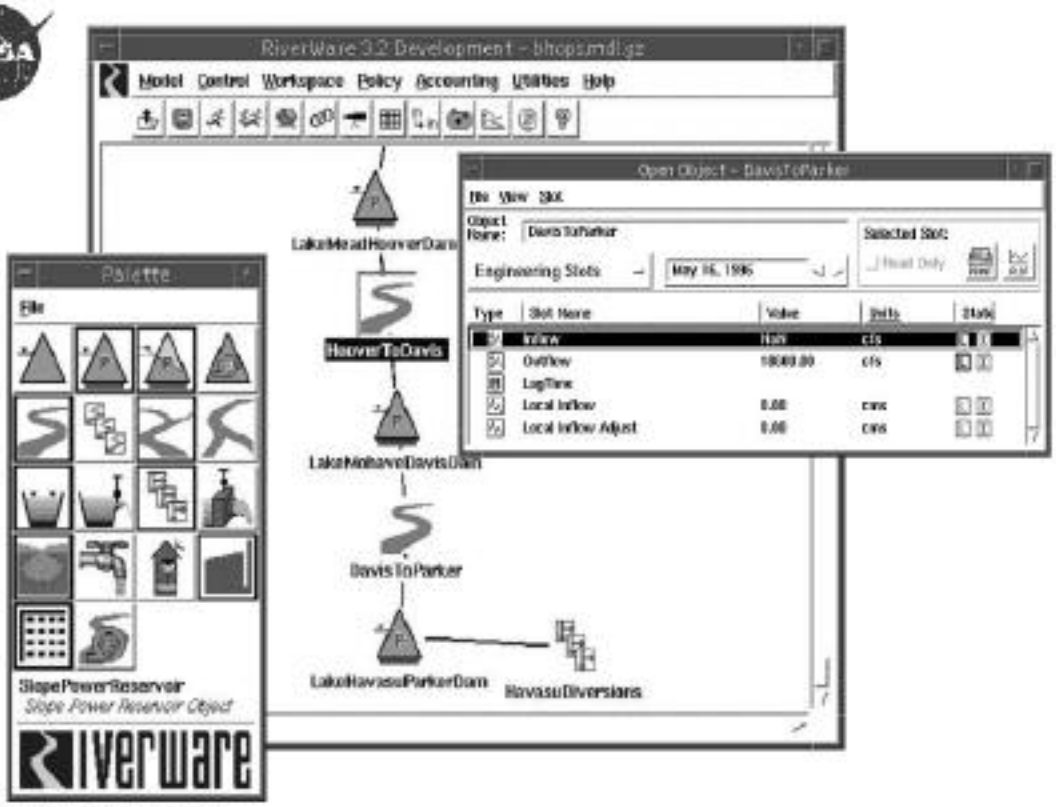
- RiverWare is a generalized, interactive object-oriented software modeling tool that can be used to develop multi-objective simulation and optimization models of river and reservoir systems.
- RiverWare can be used for managing multiple system objectives and processes that include:
  - Water quality and supply
  - Flood control
  - Navigation and recreation
  - Fish and wildlife habitat
  - Hydropower production

RiverWare

Object-Oriented Modeling Approach

- RiverWare model consists of a network of linked "objects" that represent features of river and reservoir systems.
- Objects are named and contain their own data.
- Objects contain their own physical process algorithms appropriate to a range of computational time steps.
- Information passes from one object to another via links connecting specific data structures, e.g., outflow of a reservoir is linked to inflow of a downstream river reach.
- Approach allows modeler flexibility to describe a river basin and reservoir system by customizing each object without rewriting new code.

RiverWare



User-Selectable Algorithms (Methods)

Method categories for each object type

User selects methods based on: time-step size, available input data, required outputs, institutional requirements

Power reservoirs → Power calc category
plant power, unit generator power, peak power, Lower CO River power

Reaches → Routing category
no routing, timelag, impulse-response, Muskingum, Muskingum-Cunge, kinematic

RiverWare

Three Solution Approaches

1. Simulation

   Models physical processes for a variety of input/output combinations – executed by a "controller," one object at a time. (upstream/downstream; forward/backward in time)

2. Rulebased Simulation

   Simulation driven by user-specified, prioritized operating rules (policies) expressed through an interpreted language – provides logic for determining operational decisions such as reservoir releases.

3. Optimization

   Linear goal programming solution – user finds optimal solution for each of a number of prioritized goals over the entire network and time horizon.

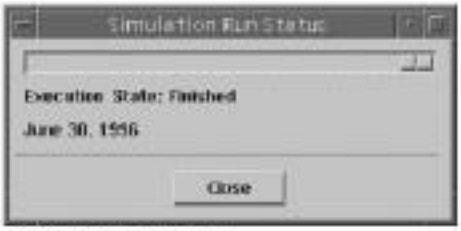
Run Control

Select Controller

Simulation
Rulebased simulation
Optimization
Post Simulation Accounting
Inline Simulation and Accounting
Inline Rulebased Simulation & Accounting

Select Time Step

1 Hr, 6 Hr, 12 Hr, Daily, Weekly, Monthly, Yearly



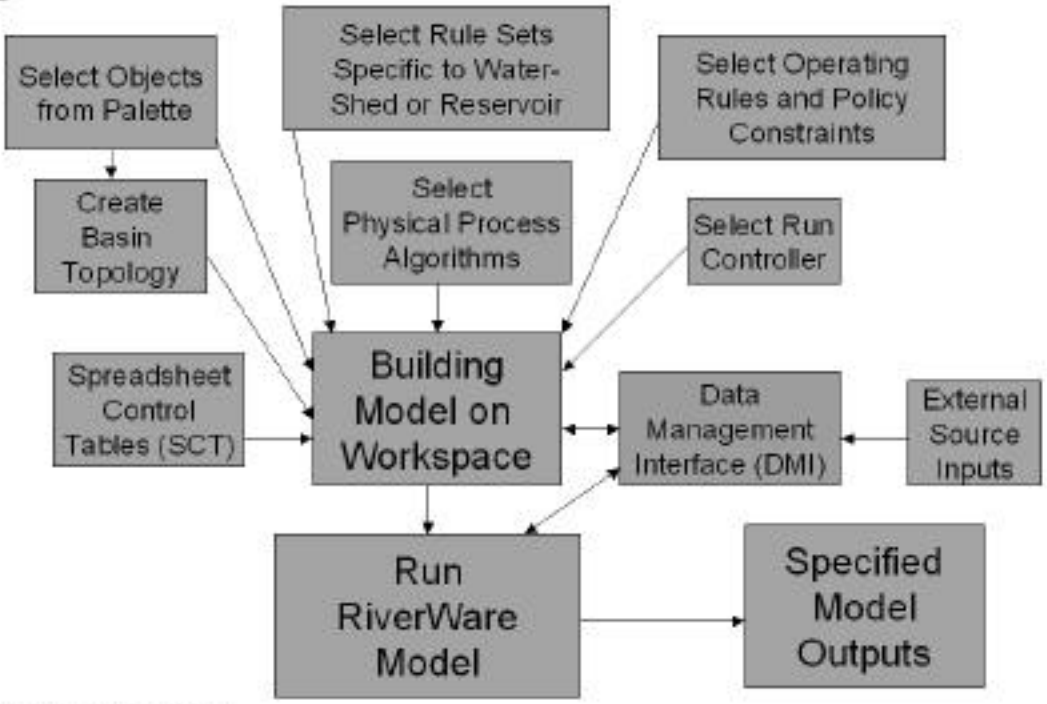
Select Run Times

Control Execution via Buttons
Run Status

RiverWare Inputs

- Input Options Available to the User Include the Following Parameters:
  - Objects (features of the river basin) which can be opened to show a list of two basic types of slots
    - Time series (inputs and outputs)
    - Tables (functional relationships and parameters)
  - Rule sets
  - Operating and policy constraint sets
  - Run controller selection: simulation, rulebased simulation or optimization
  - Time step for model runs
  - Run times
  - Physical process algorithms to be used
  - External source inputs
- From External Sources
  - Real-time or relational databases
  - Outputs from other models
  - ASCII files

RiverWare Operational Concept



Data Management Interface

- Import or export data from/to any external source (files, databases)
- Create external routines to tailor your applications
- Define the DMI and execute it from within the RiverWare user interface
- Extend or redefine start/stop time of the runs
- Group DMIs together for operational updates

RiverWare Outputs

- Outputs are completely dependent on the data inputs and policies chosen by the user for each model run
- Output Calculations from the following generic features are:
  - Storage Reservoir: Mass balance, including evaporation, precipitation and bank storage, releases, regulated and unregulated spill; and sediment accumulation
  - Power Reservoir: Storage reservoir processes plus turbine releases, hydropower and energy and tailwater elevation
  - Slope Power Reservoir: Storage and power reservoir processes plus wedge storage reservoir routing values
  - Pump Storage Reservoir: Power reservoir processes plus pumping power and energy values
  - Inline Pump/Generator: Pumping/generating power and energy and turbine/pump flow
  - River Reach: Flow routes and gains and losses

RiverWare

RiverWare Outputs (Continued)

- Output Calculations (continued):
  - Confluence: Mass balance at a river confluence
  - River Gage: Measured or forecasted flows
  - Water Users: Depletion (consumption), groundwater and surface water return flow.
  - Diversion: Gravity or pumped diversion structures
  - Aggregate Delivery Canal: Off-line delivery canals
  - Groundwater Storage: Temporary aquifer storage values for return flows
  - Canal: Bi-directional flows between reservoirs
  - Thermal Object: Economics of hydropower in total hydro/thermal power systems
  - Data Object: evaluations of user-defined expressions.

RiverWare

User Benefits

RiverWare is a tool for allowing the user to achieve improved water management. The tool can benefit users in the following areas:

- Short-term operational scheduling of flows, levels and hydropower
- Mid-term operational forecasting
- Long-term planning and analysis
- Design of new system components or new operating policies
- Multi-objective decision making for operations, policy or design of new structures
- Federal Energy Regulatory Commission's (FERC) relicensing studies
- Research and teaching in the area of water resources planning and management

RiverWare

RiverWare Users

- U.S. Bureau of Reclamation Offices in CO, ID, NM, NV, TX, UT, WA
- Tennessee Valley Authority, Knoxville, TN
- U.S. Army Corps of Engineers, Tulsa District, Tulsa, OK and Kansas City Districts, MO
- National Park Service
- Bureau of Indian Affairs
- Arizona Department of Water Resources
- Kansas Water Office
- New Mexico Interstate Stream Commission
- Colorado DNR, Division of Water Resources, Denver, CO
- Metropolitan Water District of Southern California
- Lower Colorado River Authority, Austin, TX
- Lower Neches Valley Authority, Beaumont, TX

RiverWare Users (Continued)

- Natural Resource Consulting Engineers, Inc., Fort Collins, CO
- Ayres Associates, Fort Collins, CO
- Riverside Technology, Inc., Fort Collins, CO
- Hydrosphere Resource Consultants, Boulder, CO – evaluate Pecos River Compact Compliance
- S.S. Papadopulos & Associates, Inc., Boulder CO
- Stetson Engineers, San Rafael, CA – San Carlos Apache Water Delivery Project
- Wave Engineering, Inc., Nephi, UT
- Kentucky Water Research Institute, University of Kentucky, Lexington, KY
- Southwestern Power Administration (DOE), Tulsa, OK

Examples of RiverWare User Applications

- Tennessee Valley

TVA uses RiverWare in simulation and optimization modes for daily scheduling of more than 40 reservoirs and hydroplants at a six-hour time step. Operating considerations include controlling floods, maintaining navigable depths, protecting aquatic communities, providing suitable levels and releases for recreation, and achieving economical hydropower generation schedules.

- Colorado River

USBR has replaced both its long-term policy and planning model (Colorado River Simulation System) and its mid-term operations model (24-Month Study) for the Colorado River with RiverWare rulebased simulation models. These models are used for policy negotiations, to estimate future salinity mitigation needs, as well as to set the monthly target operations for the entire river basin.

riverware

Examples - RiverWare Applications (Cont.)

- Upper Rio Grande

An interagency team including the U.S. Army COE, the USBR and USGS, has applied RiverWare's rulebased simulation and water accounting to a daily timestep Upper Rio Grande Water Operations Model (URGWOM). The model tracks native water and San Juan-Chama transbasin diversion water to fulfill compact deliveries, international treaty obligations, Indian water rights, and private rights and contracts.

- San Juan Basin

An operations model of the San Juan River Basin in Arizona, Colorado, and New Mexico has been developed in a joint USBR and USGS effort. The model is driven by operating policies to meet water supply demands, flood control, target storages, and filling criteria in its reservoirs as well as improved habitat for the endangered humpback chub and Colorado squawfish.

riverware

Possible NASA Contributions

- Air Temperature
  - Terra MODIS
    - Spatial Resolution: 250 m, 500 m & 1000 m
  - Aqua AIRS
    - Horizontal Resolution: 13.5 km IR, 2.3 km VNIR
    - Vertical Coverage (by pressure): surface to 0.016 hPa
  - Terra ASTER
    - Spatial Resolution: VNIR - 15 m, SWIR - 30 m, TIR - 90 m
  - Sub-orbital ATLAS
    - Spatial Resolution: 2 to 5 m

RiverWare

Possible NASA Contributions (Cont.)

- Solar Radiation
  - ERBS SAGE II
    - Vertical Resolution: 1 km
    - Vertical Profile: 10 km to 40 km
  - Terra/Aqua/TRMM CERES
    - Spatial Resolution: 20 km at nadir (10 km for TRMM)
- Precipitation
  - TRMM Precipitation Radar
    - Horizontal Resolution (nadir): 4.3 km
    - Vertical Resolution (nadir): 0.25 km
    - Vertical Coverage: Surface to 15 km
  - Aqua AMSR-E
    - Spatial Resolution: from ~5 km at 89 GHz to ~50 km at 6 GHz

RiverWare References

- Website:
  http://www.usbr.gov/pmts/rivers/warsmp/riverware/index.html
  http://cadswes.colorado.edu/riverware

- Point-of-Contact:
  - Terry Fulp, *Manager*
    - USBR River Systems & Meteorology Group, Denver, CO
    - Tel.: 303 445 2470
    - E-mail: dmatthews@do.usbr.gov
  - Edith Zagona, *Director and Research Engineer*
    - CADSWES, U. of Colorado, Boulder, CO
    - Tel.: 303 492 2189
    - E-mail: zagona@cadswes.colorado.edu
  - David L. King, *Hydraulic Engineer*
    - USBR River Systems and Meteorology Group, Denver, CO
    - Tel.: 303 445 2471
    - E-mail:dking@do.usbr.gov

CMAQ
Decision Support System

"First Look" Evaluation

Air Quality Management

- Environmental Protection Agency (**EPA**) is authorized under the Clean Air Act to provide technology transfer for public benefit.
- In the Clean Air Act Amendments of 1990 (CAAA-90, Section 103), a wide range of issues were identified:
  - visibility
  - fine and coarse particles
  - indirect exposure to toxic pollutants such as heavy metals
  - semi-volatile organic species
  - nutrient deposition to water bodies
- Based on these statutes, the development of the Community Multi-scale Air Quality (**CMAQ**) is based on the mission, goals and objectives of the EPA with guidance from the Clean Air Act of 1990.

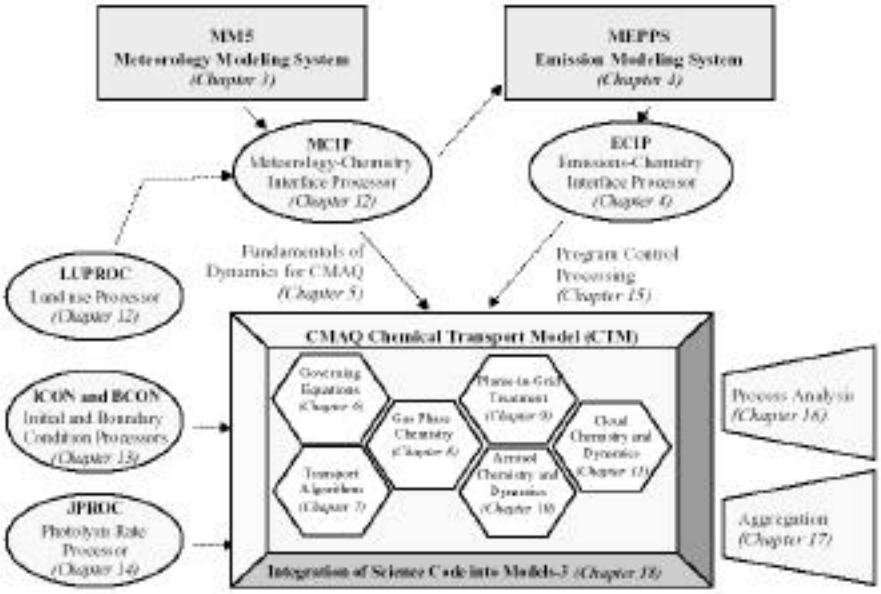
CMAQ Basic Facts

- CMAQ is the chemistry and transport component of Models-3, an integrated modeling and analysis framework.
- The CMAQ modeling system has been designed to approach air quality as a whole by including state-of-the-science capabilities for modeling multiple air quality issues, including:
  - tropospheric ozone
  - fine particles
  - toxics
  - acid deposition
  - visibility degradation
- CMAQ was also designed to have multi-scale capabilities so that separate models were not needed for urban and regional scale air quality modeling.
- CMAQ science code and its updates are available on the Internet via anonymous ftp.

CMAQ Operational Concept

- The CMAQ modeling system contains three types of modeling components:
  - Meteorological modeling system (MM5) for the description of atmospheric states and motions
  - Emission models (MEPPS) for man-made and natural emissions that are injected into the atmosphere
  - Chemistry-transport modeling system (CTM) for simulation of the chemical transformation and fate
- The CMAQ also includes six interface processors:
  - Meteorology-chemistry interface processor (MCIP)
  - Emissions-chemistry interface processor (ECIP)
  - Photolysis rate processor (JPROC)
  - Initial conditions processor (ICON)
  - Boundary conditions processor (BCON)
  - Chemical-transport model processor (CCTM)

CMAQ Structure



CMAQ Outputs

- Computation of parameters for deep convective and shallow clouds.
- Computation of surface and planetary boundary layer parameters.
- Hourly three-dimensional emission data from separate source type files including mobile, area and point
- Computation of temporally varying photolysis rates.
- Concentration fields for individual chemical species.
- Reactions of pollutants in the aqueous phase.
- Detection of the formation of secondary aerosols.
- Simulation of plume rise and growth.
- Hourly predictions of gridded concentrations of fine and coarse mode particle mass
- Modeling atmospheric transport and deposition of semi-volatile organic compounds

CMAQ Users

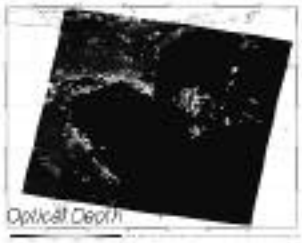
- **Foreign Users**
  - National Institute for Environmental Studies, Japan
    - air quality study in Osaka, Japan
- **Federal Agencies & Organizations**
  - EPA Office of Research & Development
  - EPA National Exposure Research Laboratory
  - EPA Regional Planning Organizations
    - Visibility Improvement - State and Tribal Association of the Southeast (VISTAS)
    - Central States Regional Air Partnership (CENRAP)
    - Midwest RPO
    - Mid-Atlantic/Northeast Visibility Union (MANE-VU)
    - Western Regional Air Partnership (WRAP)
  - National Park Service
- **Other Regional Organizations & Agencies**
  - Lake Michigan Air Directors Consortium (LADCO)
    - investigates air quality problems for member states of IL, IN, MI and WI
  - Tennessee Valley Authority
    - 1999 Nashville, TN, air quality study
  - Regional Air Quality Council of Denver
    - planning agency for 7 counties
- **State Agencies**
  - California Environmental Protection Agency
    - air quality applications in So. CA
  - California Air Resource Board
    - initiates strict guidelines for state of CA
  - North Carolina Department of Environment and Natural Resources, Division of Air Quality
  - Texas Natural Resource Conservation Commission (TNRCC)
- **Consultants and Private Industry**
  - American Petroleum Institute
  - Atmospheric & Environmental Research, Inc. – Cambridge, MA
  - ENVIRON – domestic offices and worldwide
  - Sonoma Technology, Inc. – Petaluma, CA
  - Ford Research Laboratory – Dearborn, MI
  - EPRI – Palo Alto, CA and worldwide – nonprofit organization
- **Universities**
  - University of California at Riverside
  - University of North Carolina at Chapel Hill

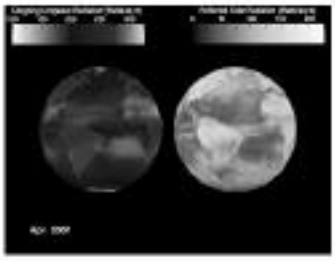
CMAQ Inputs

- Gridded atmospheric data that have at least these variables:
  - sea-level pressure, wind, temperature, relative humidity and geopotential height; and at these pressure levels: surface, 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100 hPa
- Topography
- Land use information
- Earth's surface albedo
- Vertical ozone profiles
- Total ozone column and turbidity
- Temperature profiles
- Aerosol number density profiles
- Emission inventory data
- Observation data that contains soundings and surface reports

Possible NASA Contributions

- Atmospheric particles & trace constituents
  - Terra MOPITT
    - Horizontal Resolution: 22 km at nadir
    - Vertical Resolution: 3 km
  - Terra MODIS
    - Spatial Resolution: 250 m, 500 m & 1000 m (29)
  - Earth Probe TOMS
    - Horizontal Resolution: 3° IFOV, 38 km at nadir
    - Vertical Resolution: ~5 km
    - Vertical Coverage: Surface to ~58 km
  - Aqua AIRS
    - Horizontal Resolution: 13.5 km IR, 2.3 km VNIR
    - Vertical Coverage (by pressure): surface to 0.016 hPa
- Extraterrestrial Irradiation
  - ERBS SAGE II
    - Vertical Resolution: 1 km
    - Vertical Profile: 10 km to 40 km
  - Terra/Aqua/TRMM CERES
    - Spatial Resolution: 20 km at nadir (10 km for TRMM)



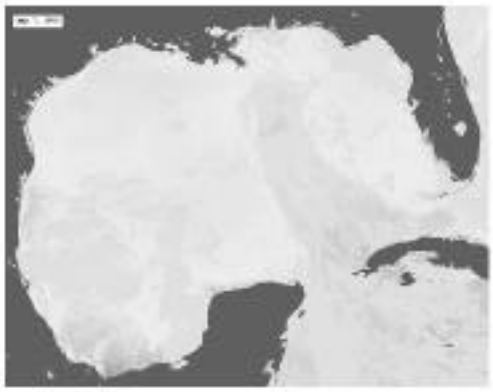


CMAQ References

- Publications:
  - *Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System*, D.W. Byun and J.K.S. Ching, Eds., EPA/600/R-99/030, Washington, DC, March 1999
  - *Alternative small scale meteorology input to a chemical transport model*, K.I. Lazarova, Ph.D. Thesis, Drexel University, Philadelphia, PA, 2001 (available online at URL http://thesis.library.drexel.edu/archive/00000029/)
- Websites:
  - EPA: http://www.epa.gov/asmdnerl/models3/cmaq.html
  - CMAS: http://www.cmascenter.org/
- Point-of-Contact:
  - Kenneth L. Schere
    CMAQ Program Manager
    Environmental Protection Agency
    E243-03
    USEPA Mailroom
    Research Triangle Park, NC 27711
    Tel.: 919-541-3795
    E-mail: schere.kenneth@epa.gov

HAB Bulletin and HABMapS Decision Support Systems

"First Look" Evaluation



Coastal Management

- Concerns about harmful algal blooms (HABs) have increased in recent years largely because of the perceived raise in the number and duration of HAB events.
- The Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) was signed into law on November 13, 1998, becoming P.L. 105-383.
- The Act recognized that many of our nation's coastal areas suffer from harmful algal blooms and hypoxia each year, threatening coastal ecosystems and endangering human health.
  - Toxins produced by these algal species cause finfish and shellfish poisoning, and mortality of marine animals, including mammals and birds.
  - Socioeconomic losses in the U.S. from HAB events amount to $47 million per year:
    - Additional healthcare costs
    - Decline in property values
    - Lost aquaculture production: massive fish kills, closures of shellfish beds
    - Decline in revenues from tourism: beach closures
- Advance warning of HABs increases the options for managing these events.
- National Oceanic and Atmospheric Administration (**NOAA**) developed decision support systems, **HAB Bulletin** and HAB Mapping System (**HABMapS**), that provide information on the location and extent of developing and existing red tide blooms in the Gulf of Mexico.

HAB Bulletin and HABMapS Basic Facts

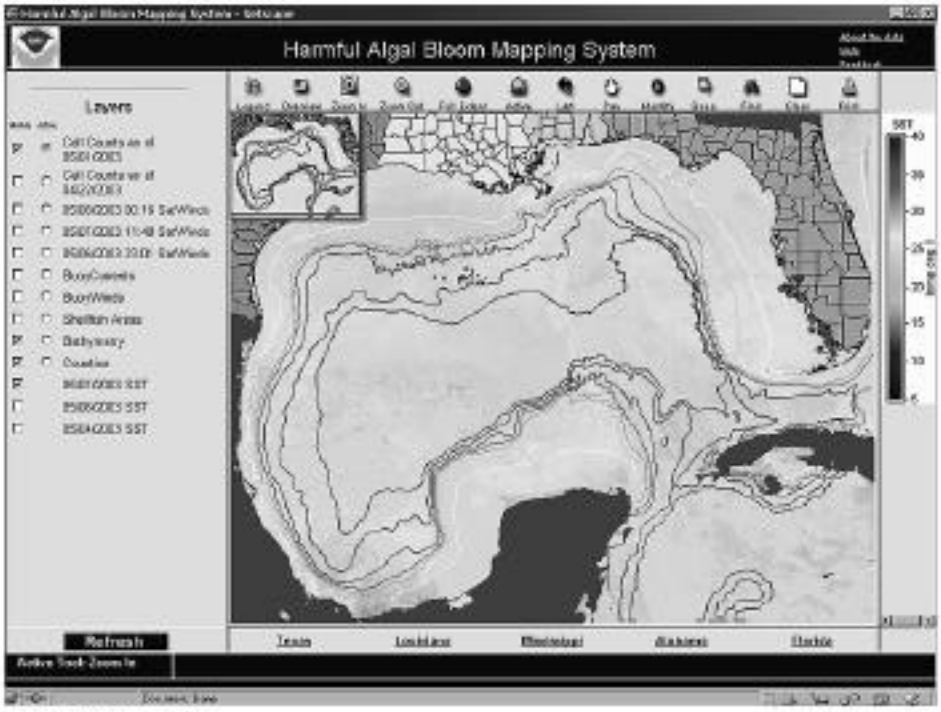
- **HAB Bulletins** are generated by the NOAA National Ocean Service and the National Environmental Satellite Data and Information Service to provide notification of bloom conditions to state and local coastal managers in the Gulf of Mexico.
  - HAB Bulletins are sent via e-mail to registered users during a bloom event.
  - They are also available on the CoastWatch website.
  - Bulletins are distributed in the Adobe Portable Document Format (PDF).
- The **HABMapS** is an interactive mapping tool that can be used to access recent data on harmful algal blooms in the Gulf of Mexico and on the environmental conditions that may affect the spread of these blooms.
  - HABMapS is accessible via Internet on the NOAA Coastal Services Center server; only Internet browser software is required.
  - HABMapS is a component of the Harmful Algal Blooms Observing System (HABSOS).

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

HAB DSSs Operational Concept

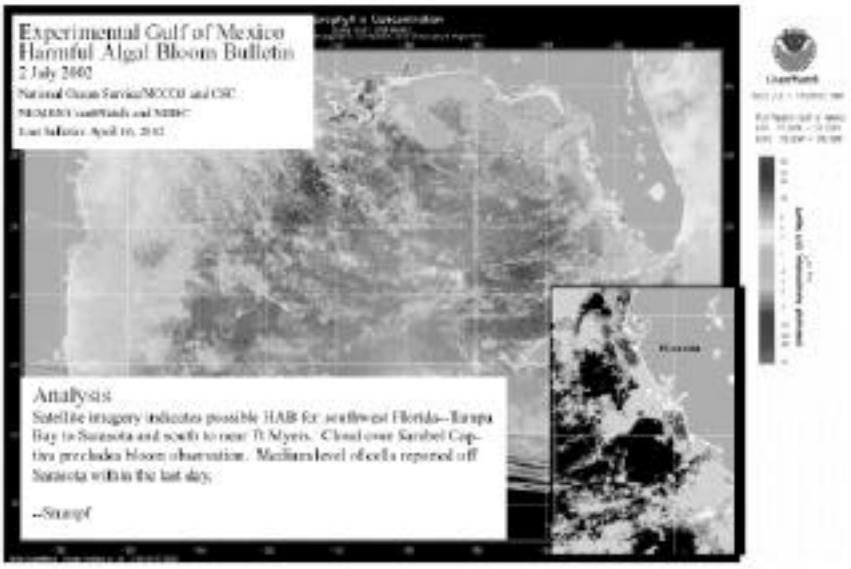
- The experimental HAB Bulletin alerts subscribers to developing blooms and changes in the location and extent of existing blooms.
- The HAB Mapping System (HABMapS) provides the position of an identified bloom and data from environmental conditions that may affect the extent or position.
- Both tools rely on remote sensing technology to provide the large spatial scale and high frequency of observations required to assess bloom location and movements.
- These tools can be used together to provide a regional perspective on HAB events.
- The tools are currently designed to address *Karenia brevis*, formerly *Gymnodinium breve*, blooms in the Gulf of Mexico, but further development of the DSSs is expected.

HABMapS Operational Concept



HAB Bulletin Outputs

- HAB Bulletins include information on wind conditions, chlorophyll levels, and potential or actual bloom events.



HABMapS Outputs

- HABMapS provides the following data layers:
  - **Sea Surface Temperature** (SST) from the Advanced Very High Resolution Radiometer (AVHRR) instruments mounted on the NOAA Polar Operational Environmental Satellites (POES)
    - 1-km spatial resolution
    - available for previous 3 days
    - updated nightly
  - **Wind speed and direction** from NOAA National Data Buoy Center (NDBC) buoys
    - updated every 6 hours
  - **Wind speed and direction** from the SeaWinds instrument on the NASA QuikSCAT satellite
    - available for the last 33 hours
    - updated nightly
  - **Sea surface current speed and direction** from Texas Automated Buoy System (TABS) buoys
    - updated every 6 hours
  - *In situ* **cell counts** for red tide
    - updated when data become available
  - **Bathymetry contours** generated from a map created for the U.S. Department of the Interior
  - **Shellfish beds** in the Gulf of Mexico as represented in the National Shellfish Register of Classified Growing Waters
    - published most recently in 1995

HAB Bulletin & HABMapS Users

- **Federal Agencies**
  - NASA – SeaWiFS Project
  - EPA – Gulf Coast Program
  - EPA – National Health and Environmental Effects Research Laboratory, Gulf Breeze/Office of Research and Development
  - Department of Energy – Office of Science – Pacific Northwest National Laboratory
  - NOAA National Environmental Satellite, Data, and Information Service (NESDIS) CoastWatch
  - NOAA NESDIS National Coastal Data Development Center
  - NOAA National Marine Fisheries Service Headquarters
  - NOAA National Ocean Service (NOS) Center for Coastal Ocean Science
  - NOAA NOS Coastal Services Center
  - NOAA NOS Estuarine and Reserve Division
  - NOAA NOS Science Office
- **State and County Agencies**
  - Alabama Department of Public Health
  - Florida Department of Environmental Protection
  - Florida Department of Agriculture and Consumer Services – Division of Aquaculture
  - Florida Fish and Wildlife Conservation Commission – Florida Marine Research Institute
  - Louisiana Department of Health and Hospitals
  - Texas Parks and Wildlife Department
  - Texas Department of Health
  - Collier County Government, Florida
- **University and Non-Profit Organizations**
  - Mote Marine Laboratory – non-profit organization in Sarasota, FL
  - University of Texas Marine Science Institute
  - University of New Hampshire
  - University of Southern Mississippi

HAB Bulletin & HABMapS Inputs

- Ocean color
- Sea surface temperature
- Sea surface height
- Surface waves and fronts
- Wind fields from satellite imagery
- Laser fluorescence imagery
- Salinity concentrations
- Local currents
- Land use/land cover information
- Coastline topography
- Coastal impervious surface amounts
- Local algae cell counts
- Bathymetry
- Shellfish bed locations
- Locational data layers
- Buoy winds and currents
- Temporal scale of sediment concentration settling decay

Possible NASA Contributions

- Ocean color, sea surface temperature, chlorophyll concentration
  - Aqua/Terra MODIS
    - 1-km GSD MOD18 to MOD28, MOD31, MOD36, and MOD37 ocean data products
- Wind speed and direction
  - ADEOS II SeaWinds
    - 50-km GSD wind vector fields
- Land use/land cover data
  - Landsat 7 ETM+
    - 15-m GSD pan-sharpened multispectral images
  - Terra ASTER
    - 15-m GSD multispectral images
- Coastline topography
  - Shuttle Radar Topography Mission (SRTM)
    - 30-m GSD Digital Elevation Model



HAB Bulletin & HABMapS References

- D.M. Anderson, P. Hoagland, Y. Kaoru, and A.W. White, *Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States*, Technical Report, Woods Hole Oceanographic Institution, September 2002
- Websites:
  - http://www.csc.noaa.gov/crs/habf/
  - http://coastwatch.noaa.gov/hab/
- Subscriptions and help:
  - E-mail: csc@csc.noaa.gov
- Point-of-Contact:
  - Mary Culver
    Coastal Services Center
    National Oceanic and Atmospheric Administration
    Charleston, SC
    Tel.: 843 740 1250
    E-mail: Mary.Culver@noaa.gov

BASINS

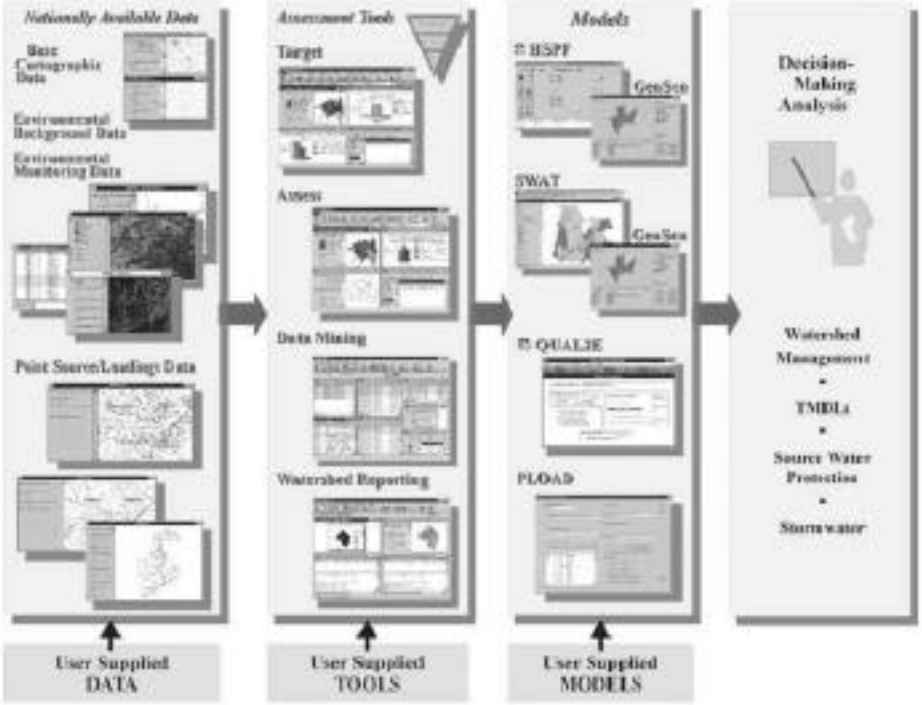
Better Assessment Science Integrating Point and Nonpoint Sources

NASA Feasibility Assessment

BASINS Basic Facts

- BASINS is a multipurpose environmental analysis software for use by regional, state, and local agencies in performing watershed and water quality based studies. It allows users to assess water quality at selected stream sites or throughout an entire watershed.
- Consists of a suite of interrelated components – databases and assessment tools integrated within the ArcView 3.x environment.
- Originally released in 1996; Version 3 is the current version. Version 4 is expected to be released in the fall of 2003.
- BASINS has three major objectives:
  - To facilitate examination of environmental information
  - To support analysis of environmental systems
  - To provide a framework for examining management alternatives

BASINS Operational Concept



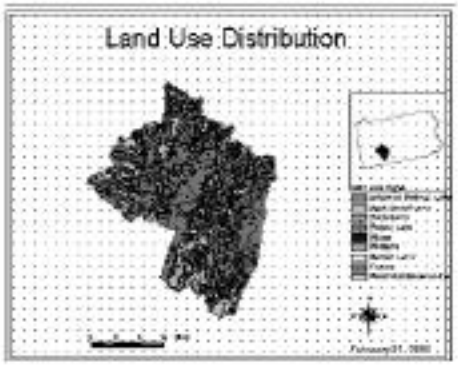
BASINS User Levels

- BASINS has three geographically based analytical tools for regional and site-specific analysis
  - **TARGET** enables a broad-based evaluation of a watershed's water quality and/or point source loadings. It is designed to perform analysis on the entire area extracted (e.g. EPA regions, state).
  - **ASSESS** operates on a single or limited set of watersheds and focuses on the status of specific water quality stations or discharge facilities and their proximity to water bodies.
  - **Data Mining** lets BASINS users more fully access the water quality and point source databases. Data Mining complements both TARGET and ASSESS by allowing users to progress from a regional analysis to a site-specific analysis.
- BASINS provides a choice of in-stream, watershed, and loading models.
  - **QUAL2E** is a one-dimensional water quality model that allows analysis of pollutant fate and transport of both point and non-point source loadings through selected stream systems.
  - **HSPF** is a watershed model that simulates non-point source runoff and pollutant loadings for a watershed and performs flow and water quality routing in reaches.
  - **SWAT** is a physical based, watershed scale model that was developed to predict the impacts of land management practices on water, sediment, and agricultural chemical yields.
  - **PLOAD** is simplified GIS based model for calculating pollutant loading from watersheds. It estimates non-point loads of pollution on an annual average basis for any user-specified pollutant.

BASINS Outputs

Watershed Characterization Reports

- **Point Source Inventory**
  - Provides a summary of discharge facilities and pollutant discharge loading
- **Water Quality Summary**
  - Provides a summary of water quality monitoring stations
- **Toxic Air Emission**
  - Provides a summary of facilities that are part of the TRI and have estimated air releases of a particular pollutant
- **Land Use Distribution**
  - Provides a summary of land use distribution (Anderson Level I & II Classification)
- **State Soil Characteristics**
  - Provides a summary of the spatial variability of selected soil parameters
- **Watershed Topographic**
  - Provides a statistical summary and distribution of discrete land surface elevations and an elevation map



BASINS Users

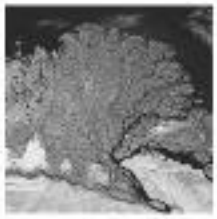
- USEPA
- Regional, State, Tribal, and Local Water Quality & Watershed Managers
  - Development of TMDLs for impaired waterways
- U.S. Army Corps of Engineers

BASINS Inputs

- **Base Cartographic Data**
  - Hydrologic, Roads, Places, State/County Boundaries, EPA Regions
- **Environmental Background Data**
  - Ecoregions, NAWQA Boundaries, STATSGO Database, Managed Area Database, Reach File (stream network for major rivers), National Hydrography Dataset, DEM, LULC, National Inventory of Dams
- **Environmental Monitoring Data**
  - Water Quality Monitoring Stations, Bacteria Monitoring Stations, National Sediment Inventory Stations, Fish & Wildlife Advisories Lists, Gage Sites, Weather Stations, Drinking Water Supply Sites, Watershed Data Stations, Classified Shellfish Areas
- **Point Source/Loading Data**
  - Permit Compliance System Sites and Computed Annual Loadings, Industrial Facilities Discharge Sites, Toxic Release Inventory Sites and Pollutant Release Data, Superfund National Priority List, RCRIS Sites, MAS/MILS

Possible NASA Contributions

- Ground elevation data
  - Shuttle Radar Topography Mission (SRTM)
    - 30-m GSD Digital Elevation Model
  - Terra ASTER based DEM
- Land use / land cover data
  - Landsat 7 ETM+
    - 15-m GSD pan-sharpened multispectral images
  - Terra ASTER
    - 15-m GSD multispectral images
  - Terra / Aqua MODIS
    - 250-m, 500-m multispectral images
- Coastal Water Quality Algorithms
  - Although spatial resolutions of NASA missions are typically too coarse for this DSS, the algorithms for estimating water optical properties and constituents (e.g., chlorophyll concentration) in coastal areas may be applicable



NASA Workforce Experience

Land Use/Land Change Analysis

BASINS References

- Websites
  - http://www.epa.gov/ost/basins

- Point-of-Contact:

Dr. Russell Kinerson
Modeling and Information Technology Team
Standards and Health Protection Division
Office of Science and Technology
U.S. Environmental Protection Agency
Mailcode - 4305T
1201 Pennsylvania Ave., NW
Washington, DC 20460
(202) 566-0409

Coral Reef Environmental Warning System (CREWS)

NASA Feasibility Assessment

CREWS Facts

- Owner Agency:

  NOAA/Atlantic Oceanographic and Meteorological Laboratory

- Point of Contact:

  Jim Hendee
  Coral Health and Monitoring Program
  AOML/NOAA
  Miami, FL 33149-1026

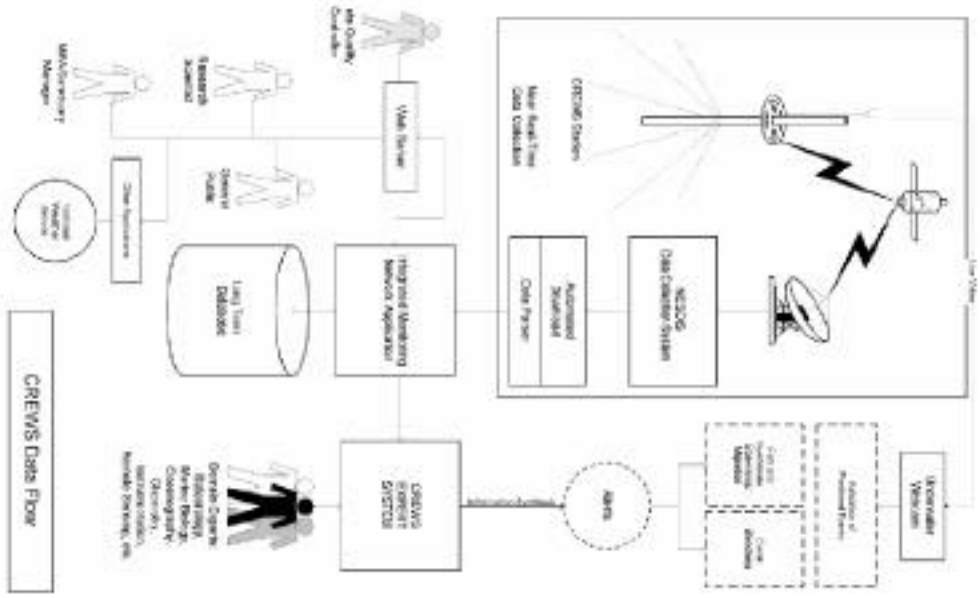
CREWS Operational Concept

The Coastal Reef Early Warning System (CREWS) produces automated electronic mail and World-Wide Web alerts when conditions are thought to be conducive to, or predictive of, coral bleaching. Data from remote sites are collected continuously and transmitted via satellite to Wallops Island Virginia. The analysis of this data has been automated by a near real-time rule-based expert system which produces the predictions and alerts. CREWS operates under the NOAA Coral Health and Monitoring Program (CHAMP).

CREWS can be extended to monitor additional parameters and prepare alerts to other biological and natural events.

Installation of new meteorological and oceanographic monitoring stations is underway (e.g., Lee Stocking Island, NW Hawaiian Islands, St. Croix). Remote stations can cost up to $150K. Permitting for new sites can be difficult. Stations need maintenance.

CREWS Operational Concept (cont'd)



CREWS Outputs

- E-mail and internet alerts when conditions are thought to be conducive to, or predictive of, coral bleaching.

CREWS Inputs

- Wind speed
- Sea temperature
- Salinity
- Transmissometry
- Photosynthetically Active Radiation (PAR)
- Ultraviolet light
- Tide level

Possible NASA Contributions

- Several CREWS input parameters are available via remote sensing. Wind speed is available from NASA QuikSCAT. Sea surface temperature is available from NOAA/AVHRR and MODIS on NASA Terra and Aqua missions. MODIS also produces a PAR product, water turbidity products, and several chlorophyll fluorescence products which would be indicators of coral reef health.
- If CREWS relied more heavily on satellite data, construction, maintenance, and permitting issues would be minimized.
- CREWS is a real-time system which means that NASA imagery must be processed operationally with quick turn-around (maybe 24-48 hours) to be useful in this application.
- There is synergy with the ReefBase DSS.

Possible NASA Contributions (cont'd)

- Satellite data is already included in CREWS in some fashion. NOAA reports that CREWS is used together with NOAA's satellite-monitored high sea temperature ('HotSpot') data and biological monitoring data. The role presently played by satellite data (if any) in CREWS is not clear at this time.

NASA Workforce Experience

Coastal Water Quality

- **Carlos Del Castillo**, **Richard Miller**, **Callie Hall**, **Bruce Spiering** (Stennis), Coastal remote sensing applications development
- **Frank Hoge** (Wallops), Lead Investigator for Ocean Color Development and Validation
- **John Moisan** (Wallops), Lead Investigator for Coastal ocean observation, simulation, and analysis

Coral Reef Mapping and Health Assessment

- **C. Wayne Wright** (Wallops), Lead Investigator for Experimental Advanced Airborne Research LiDAR (EAARL), Seagrass and coastal habitat applications
- **Liane Guild** (Ames), Ecosystem Science and Technology Branch, Remote sensing of coral reef health

Remote Sensing of Phytoplankton Physiology and Taxonomy

- **Alexander Chekalyuk** (Wallops), Lead Investigator for Advanced Coastal Laser Biomonitoring, Phytoplankton physiological assessment using superactive-active-passive (SAP) systems

CREWS References

- Website: http://www.coral.noaa.gov/crw/process.shtml
- Publication:

Hendee, J.C., C. Humphrey, and T. Moore. A data-driven expert system for producing coral bleaching alerts. *Proceedings of the 7th International Conference on Development and Application of Computer Techniques to Environmental Studies*, eds. D.W. Pepper, C.A. Brebbia, and P. Zannetti, Computational Mechanics Problems/WIT Press, Southampton, pp. 139-147, 1998.

Hendee, J. A layman's guide to the CREWS network. http://www.coral.aoml.noaa.gov/crw/crews_layman.pdf

GNOME

General NOAA Oil Modeling Environment
Decision Support System

First-Look Evaluation

Coastal Management

- **Federal, state, and local coastal managers levels are responsible for**
  - coastal resources planning
  - environmental compliance
  - event response

- **Coastal management issues include**
  - Harmful algal blooms
  - Benthic mapping
  - Community growth
  - Coastal water quality
  - Anoxia/hypoxia
  - Sea level rise
  - Coastal inundation/erosion
  - Wetland assessment
  - Coastal habitat conservation

The purpose of the Coastal Management National Application is to evaluate and benchmark NASA data, assimilation techniques, and technologies to support operational coastal decision support and coastal NSDI

GNOME Coastal Management

- **GNOME is a free computer program downloadable from the Internet**
  - Predicts how wind, current, river flow, and tidal processes might spread an oil spill across water over a specified period of time
  - Teaches how predicted oil trajectories are affected by unpredictability of current, wind observations, and forecasts
  - Describes how spilled oil is predicted to change chemically and physically over time
  - Can be used by the general public for educational purposes or by professionals in the diagnostic mode to input exact vital statistics
  - Contains a GIS extension that can be downloaded, installed, and used in ArcView
- **Users enter a spill scenario description into the program**
  - GNOME creates and displays an oil spill movie showing a best-guess predicted trajectory and associated minimum regret (uncertainty) for your scenario over a specified time period
  - Files containing prepackaged map, tide, and current information for 20 locations worldwide can be downloaded from the Internet

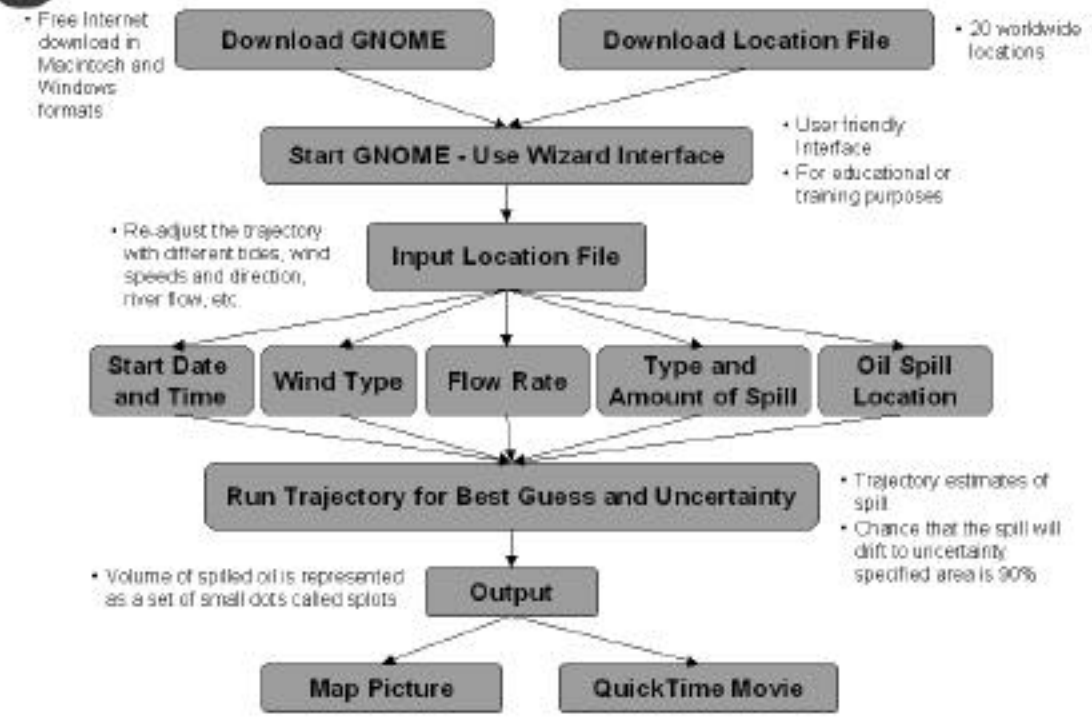
GNOME Facts

- **Developed by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic & Atmospheric Administration Office of Response and Restoration (NOAA/OR&R)**
- **Uses surface and wind-driven current information, tidal tables, and river flow rate calculations to predict oil trajectory**
- **Uses weathering algorithms to make simple predictions about the changes the oil will undergo while exposed to the environment over time**
- **Three model modes:**
  - Standard Mode – Uses preloaded data, such as area map, tidal information, and dominant current patterns, most common in specified area in downloaded location files
  - GIS Mode – Trajectory can be output in a georeferenced format that can be used as input to GIS program as georeference point shapefiles
  - Diagnostic Mode – Provides full tactical support of actual spill response for expert modeling by professionally trained personnel with real-time weather, current, and tide data

GNOME Facts

- **Each location file contains generalized information about the tides, currents, and shorelines and is unlikely to represent conditions existing at any particular time at the depicted location**
  - Location files are used only to create spill scenarios for training and educational purposes, not for actual spill response
  - Report any oil or chemical spills in U.S. waters to the U.S. Coast Guard National Response Center at 1-800-424-8802
- **Initial drill estimates of oil spill trajectory are made within one hour of actual spill time**
- **Can quickly be updated, re-run, and saved with new information**
  - Reinitializing of GNOME trajectory in response to over flight to locate slicks and sheens of oil on water visually
- **Unified Command might select protective strategies, such as placing booms or skimmers, to prevent or minimize the amount of oil penetration to sensitive areas**
  - Shellfish beds
  - Marshland
  - Seabird nesting on rocks or islets
  - Marinas

GNOME "Standard" Operational Concept

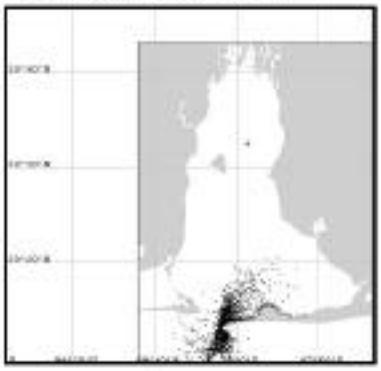


Standard GNOME Printout Example

Model Mode: Standard
Estimate for: 18:00 08/01/03
Prepared : 12:07 08/05/03

Scenario Name: Mobile Bay Scenario 3
Prepared by: Roxzana Moore
Contact Phone: 228-688-7241

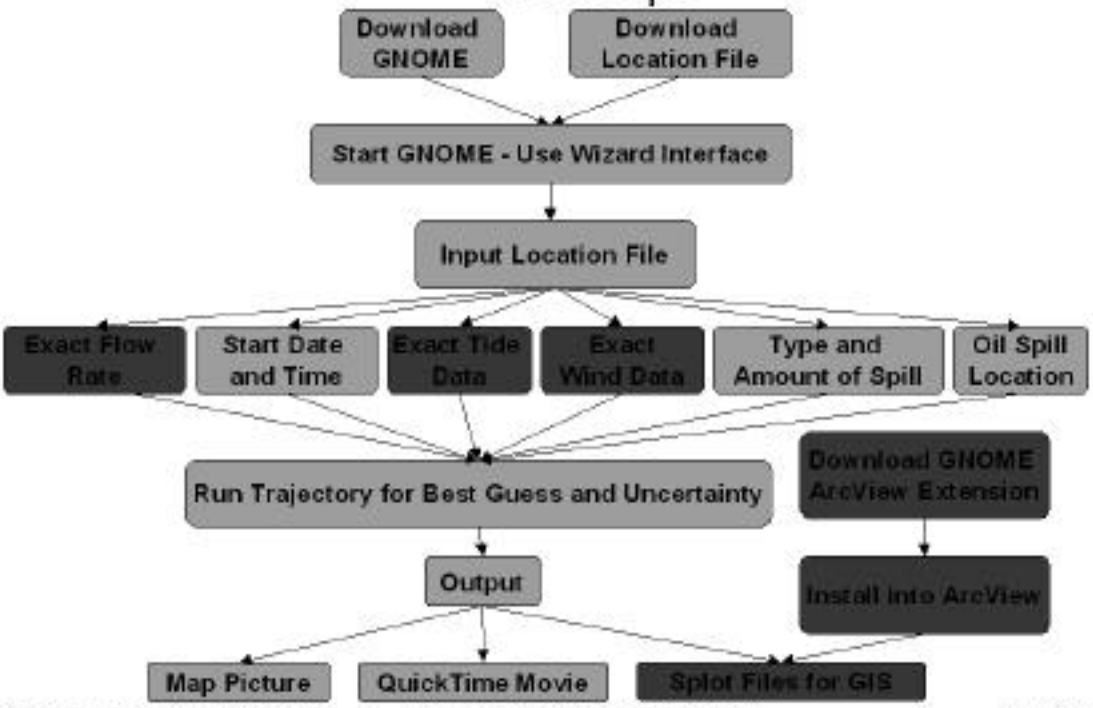
This trajectory was created using climatologically currents from a GNOME Location File and is unlikely to represent conditions existing at any particular time at the depicted location. Use Location Files only to create spill scenarios for training and educational purposes, not for actual spill response.



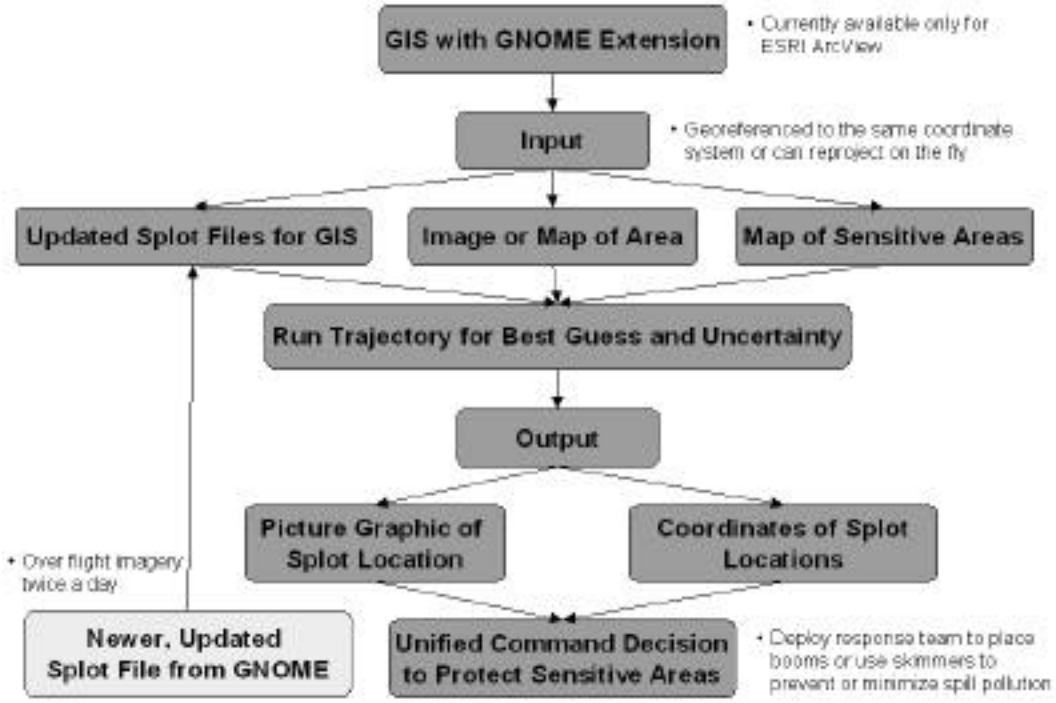
Black Splots: Best Guess, Red Splots: Uncertainty
Splot Mass Balance Totals (Best guess):
Released: 1000 barrels
Evaporated and dispersed: 253 barrels
Beached: 589 barrels
Off Map: 0 barrels
Floating: 158 barrels

Mobile Bay
River flow: 80 kcfs
Wind: Constant 20 knots from NE
Number of Spills: 1

GNOME "Professional" Operational Concept



GNOME "Reinitialize" Operational Concept

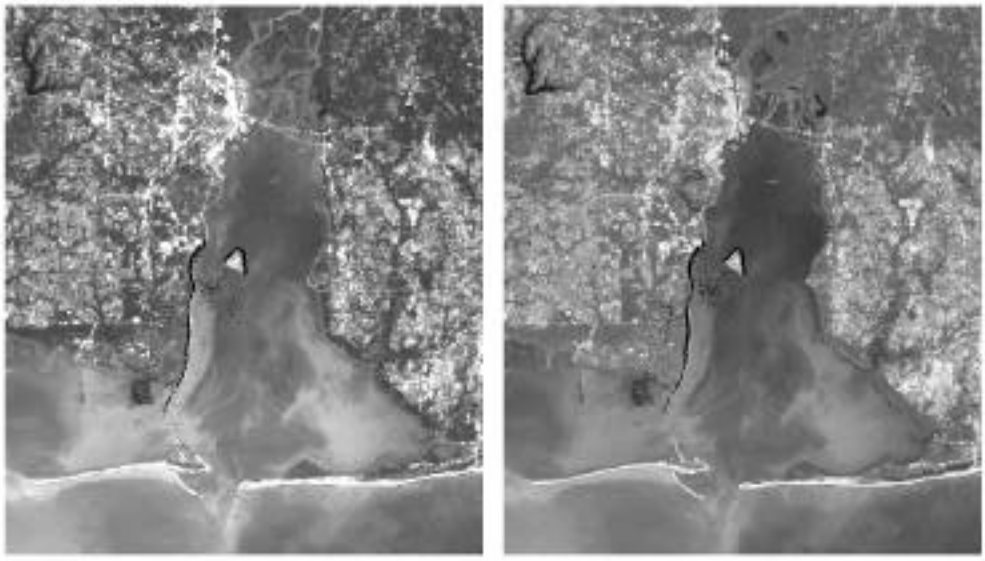


GIS Layout Printout Example

Mobile Bay Oil Spill Scenario 4

Time of Spill: July 31, 2003
Duration: 30 hours after spill
Prepared by: Roxzana Moore
Phone: 228-688-7251

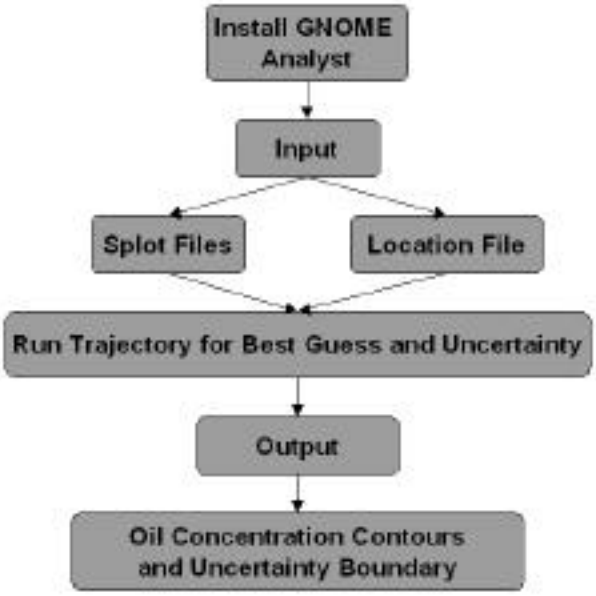
This trajectory was created using climatologically currents from a GNOME Location File and is unlikely to represent conditions existing at any particular time at the depicted location. Use Location Files only to create spill scenarios for training and educational purposes, not for actual spill response.

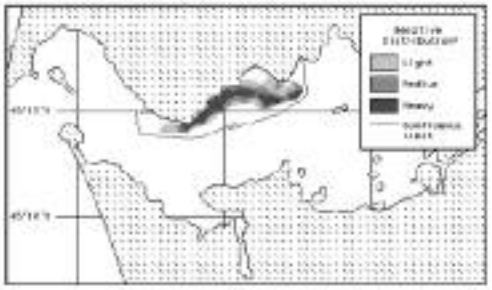


Natural color | Infrared

GNOME "Analyst" Operational Concept

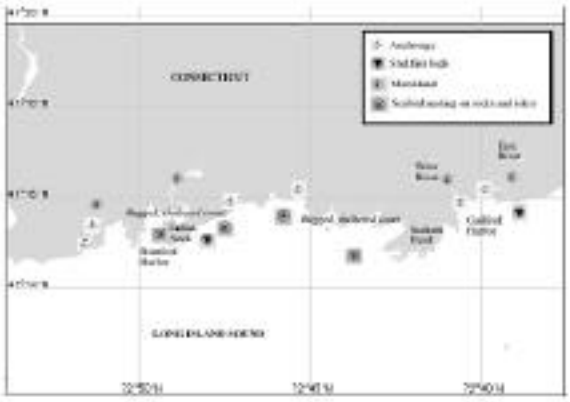
- Point data from GNOME can be read into a companion program, GNOME Analyst, which can derive oil concentration contours





GNOME Outputs

- Map picture printout showing distribution of splots that occurred over time at a particular location
- QuickTime movie showing movement of the splots for a particular scenario run in GNOME
- Splot files in GIS format for incorporation into GIS program
- BNA map file for GNOME Analyst
- Wind data files for use in NOAA HAZMAT's oil weathering program

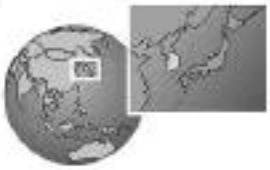


Map of sensitive area that can be used with splot files in GIS

GNOME Users

- **General public for educational use**
  - Public awareness that a trajectory model exists and can be used to determine the approximate spread of a spill if current, wind, river flow, amount of spill, and tide parameter are defined and run in the model
  - Learn how to include uncertainty in observations and forecasts to improve estimate of spill impact area
- **Professional use for training to improve skill and intuition in trajectory analysis**
- **Professional use by trained personnel if exact current, wind speed and direction, river flow, amount of spill, and tidal information parameters are recorded in the Diagnostic Mode**
  - Designed for expert modelers who provide tactical support for spill response team
  - Requires hydrodynamic modeling experience and advanced training from NOAA HAZMAT
- **Unified Command team that will use the trajectory predictions to determine where to implement countermeasures by sending the response teams to place booms and skimmers to prevent or minimize spill spread to sensitive areas**

GNOME Inputs

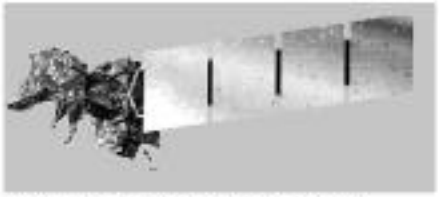


- **Location files for 20 worldwide coastal locations**
  - Navigational chart map of a specified area
  - Most common current patterns for a specified area
  - Tidal information for a specified area and time
  - Low, medium, and high river flow current data information for a specified area, if applicable
- **Weather reports and forecasts from the NOAA National Weather Service**
  - Wind flow and direction, constant or variable over time
  - Exact wind flow data for actual spill event

- **Spill location and start time**
  - Actual coordinate point representation if stationary, or line recording if drifting
  - Sprayed point representation to simulate observations from over flight information
- **Type of pollutant and amount released**
- **Time duration after spill**
- **Map of environmentally sensitive areas**

Possible NASA Contributions

- **Replace current map in GNOME model with Landsat 7 ETM orthorectified, pan-sharpened, 3-band, natural color and infrared imagery in MrSID format**
  - Reduced file size makes Internet download practical while preserving georeferencing and image quality with nearly lossless compression
  - Benefits:
    - Quick georeferencing of reconnaissance mission images using base image as reference
    - Increased interpretability of the surrounding environment and location on natural and manmade features in the vicinity of the spill
    - Immediate recognition of the coastline contaminated or in danger of contamination by a spill, eliminating the need to locate imagery and start a GIS
    - Improved usability of spray can tool used to reinitialize pollutant location and concentration on helicopter imagery while on reconnaissance missions
    - Time savings for quick command decisions to deploy response team to prevent or minimize spill spread to sensitive areas
    - Worldwide availability with 16-day temporal resolution



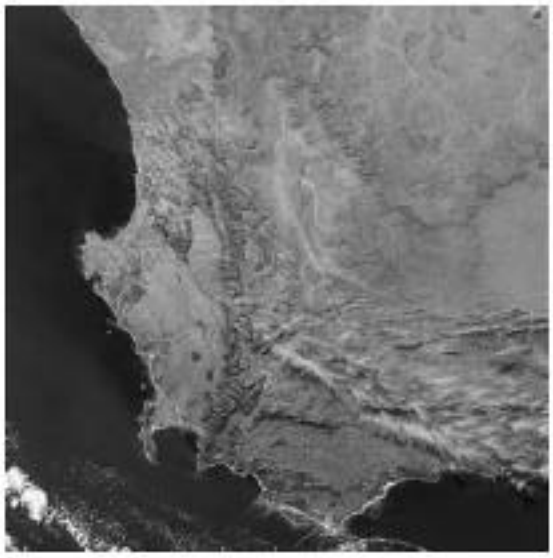
Example of Coastline Detail with Image

Landsat 7 orthorectified, 3-band, infrared, pan-sharpened imagery in MrSID format

Black splots: Best guess
Red splots: Uncertainty
- o Offshore
- + Onshore

Other Possible NASA Contributions

- **Replacement of base map with MODIS imagery from EOS satellites with 250 m to 1 km spatial and 1 day temporal resolutions in 36 spectral bands**
  - Benefits: Updated base map available daily after actual catastrophic spill



MODIS
August 5, 2003
South Africa

GNOME References

- **Web sites**
  - http://response.restoration.noaa.gov/software/gnome/gnomeinfo.html
  - http://response.restoration.noaa.gov/software/gnome/examples.html
  - http://response.restoration.noaa.gov/software/gnome/pdfs/GNOME_Manual.pdf
  - http://response.restoration.noaa.gov/software/gnome/locfiles.html
- **Publications and Internet sites containing information for each location are included in the wizard interface**
- **Internet sites for finding specific weather and tidal information for each location are included in the wizard interface**
- **Internet sites for finding flow rate data for each location are included in the wizard interface**
- **For information about training in the Diagnostic Mode, contact NOAA HAZMAT at ORR.GNOME@noaa.gov or at 206-526-6317**

Protected Areas Geographic Information System (PAGIS)

NASA Feasibility Study

PAGIS Facts

- Owner Agency:

  Joint NOAA/NOS project with the Office of Ocean and Coastal Resource Management's National Marine Sanctuary Division and National Estuarine Research Reserve Division, the Special Projects Office, and the Coastal Services Center.

- Supporting:

  The Landscape Characterization and Restoration program is supporting PAGIS by assisting with data collection and benthic habitat characterization using sediment profiling imagery, traditional benthic sampling techniques, and a RoxAnn acoustic system.

- Point of Contact:

  Charles Alexander, Chief National Programs Branch, NMSS
  NOAA's National Marine Sanctuaries
  1305 East-West Highway, 11th Floor
  Silver Spring, MD 20910
  Phone: (301) 713-3125

PAGIS Operational Concept

- The Protected Area Geographic Information System (PAGIS) provides spatial data management and Internet capabilities at all National Estuarine Research Reserves (NERR) and National Marine Sanctuaries (NMS).
- A set of standard data layers will be created and distributed to each site.
- Supports restoration documentation and planning, outreach/education, management review, permit tracking and management, and oil spill response
- Target audience is federal managers of NERRs and NMSs, researchers and educators
- Future plans
  - ✓ Incorporation of more satellite data
  - ✓ Advanced visualization tools
  - ✓ An operational GIS for all NERRS and NMS

National Marine Sanctuaries

- Channel Islands, California
- Cordell Bank, California
- Fagatele Bay, American Samoa
- Florida Keys, Florida
- Flower Garden Banks, Texas/Louisiana
- Gray's Reef, Georgia
- Thunder Bay, Michigan
- Gulf of the Farrallones, California
- Hawaiian Islands Humpback Whale critical habitat
- *USS Monitor* wreck site, North Carolina
- Monterey Bay, California
- Olympic Coast, Washington
- Stellwagen Bank, Massachusetts

National Marine Sanctuaries

National Estuarine Research Reserves

- ACE (Ashepoo-Combahee-Edisto) Basin, South Carolina
- Apalachicola Bay, Florida
- Chesapeake Bay Reserve, Maryland
- Chesapeake Bay Reserve, Virginia
- Delaware Reserve
- Elkhorn Slough, California
- Grand Bay, Mississippi
- Great Bay, New Hampshire
- Guana-Tolomato-Matanzas, Florida
- Hudson River, New York
- Jobos Bay, Puerto Rico
- Kachemak Bay, Alaska
- Jacques Cousteau Reserve, New Jersey
- Narragansett Bay, Rhode Island
- North Carolina Reserve
- North Inlet/ Winyah Bay, South Carolina
- Old Woman Creek, Ohio
- Padilla Bay, Washington
- Rookery Bay, Florida
- Sapelo Island, Georgia
- South Slough, Oregon
- Tijuana River, California
- Waquoit Bay, Massachusetts
- Weeks Bay, Alabama
- Wells, Maine

National Estuarine Research Reserves

PAGIS Inputs

- Geopolitical boundaries
- Turtle and bird nesting sites
- Topographic/nautical charts
- Land use/land cover
- Sampling locations
- Historical data
- Bathymetry
- Benthic habitat
- Navigation charts

Possible NASA Contributions

- According to the reference cited on the following slide, the greatest needs in the NERRS are

  1) Upland land cover
  2) Benthic or subtidal habitat delineation
  3) Bathymetry
  4) Water quality data

- Remote sensing could contribute to all of these. AVIRIS, CRIS, ATLAS, and Landsat, are the primary NASA resources. However, the best system to address needs 2-4 above is the new Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system with integrated LiDAR bathymetry, LiDAR topography, digital camera, and CASI hyperspectral sensors.

NASA Workforce Contribution

Coastal Land Cover

- **Bill Krabill** (Wallops), Lead Investigator for Coastline Topographic Mapping and Shoreline Elevation Change

Coastal Water Quality

- **Carlos Del Castillo**, **Richard Miller**, **Callie Hall**, **Bruce Spiering** (Stennis), Coastal remote sensing applications development
- **Frank Hoge** (Wallops), Lead Investigator for Ocean Color Development and Validation
- **John Moisan** (Wallops), Lead Investigator for Coastal ocean observation, simulation, and analysis
- **Alexander Chekalyuk** (Wallops), Lead Investigator for Advanced Coastal Laser Biomonitoring

Benthic and Subtidal Habitat Delineation

- **C. Wayne Wright** (Wallops), Lead Investigator for Experimental Advanced Airborne Research LiDAR (EAARL), Seagrass and coastal habitat applications

PAGIS References

- Website: http://www.csc.noaa.gov/pagis/
- Publication:

Schuyler, Q, B. Stevenson, H. Recksiek, M. Crawford, M. Treml, Addressing Habitat Issues with Remote Sensing in the National Estuarine Research Reserve System: Needs Assessment Report, NOAA, October 2002.

ReefBase

NASA Feasibility Assessment

ReefBase Facts

- Owner Agency:

  The World Fish Center, an autonomous, non-governmental, nonprofit, international scientific and technical center which has been organized to conduct, stimulate and accelerate research on all aspects of fisheries and other living aquatic resources.

- Point of Contact:

  Dr. Jamie Oliver (Project Leader)
  World Fish Center
  ReefBase Project
  Penang, Malaysia
  Phone: +60 (0)4 626 1606
  FAX: +60 (0)4 626 5530
  reefbase@cgiar.org

ReefBase

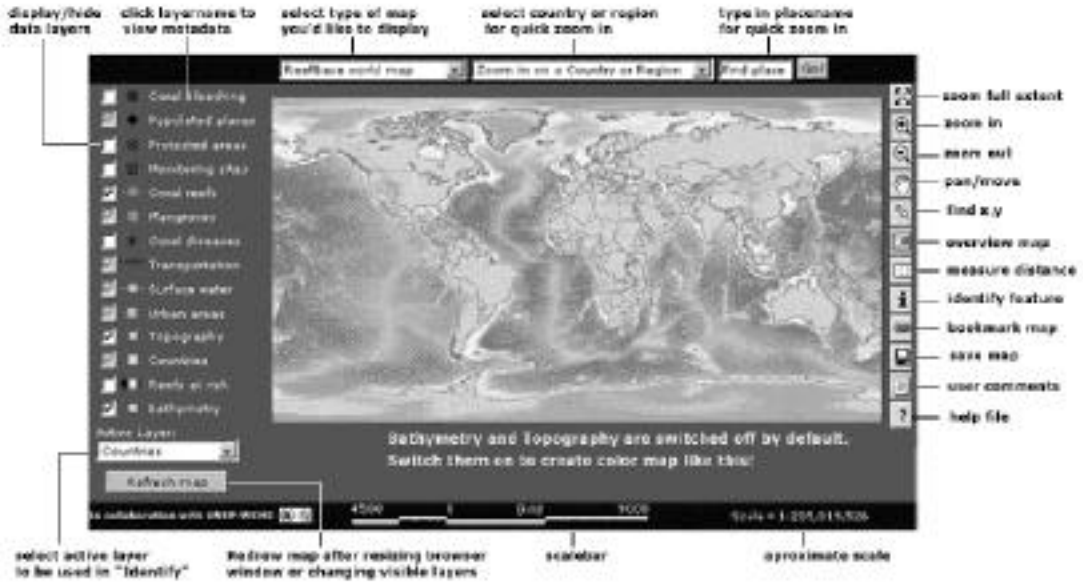
- Typical Collaborators:
  - Global Coral Reef Monitoring Network
  - International Coral Reef Initiative
  - International Coral Reef Information Network
  - NOAA's Coral Health and Monitoring Program
- Typical Funding Organizations:
  - International Coral Reef Action Network
  - Worldfish Center
  - United Nations Foundation
- Typical Content Providers:
  - UNEP's World Conservation Monitoring Centre
  - The World Resources Institute
  - NASA's Image Analysis Laboratory at Johnson Space Center
  - Association of Southeastern Asian Nations

ReefBase Operational Concept

- Develop a relational database for structured information on coral reefs that will serve as a computerized encyclopedia and analytical tool for use in reef management, conservation, and research.
- Collaborate with other national, regional, and international databases, and GIS facilities relating to reefs, and provide a means of comparing and interpreting information at the global level.
- Develop and distribute analytical routines that will make full use of the information and ensure appropriate interpretation and synthesis.
- Define criteria for reef health and use them to refine procedures for coral reef assessments and to determine coral reef status at the regional and global level.
- Determine the relationships among coral reef health, fishery production and the quality of life of people dependent on reefs.

ReefBase

ReefBase is web-based and GIS-enabled.



ReefBase

ReefBase's online geographic information system (GIS) displays coral reef related data and information on interactive maps. The data content covers such topics as

- Coral reefs
- Mangroves
- Monitoring programs
- Marine protected areas
- Coral diseases & bleaching occurrences

In addition, you can view a number of thematic maps, including:

- Coral reef area
- Fish consumption
- Biodiversity
- Reefs at risk

ReefBase Data

- Currently, there is information on over 10,000 reefs.
- Over 9,700 references are now logged into the database.
- A total of 1,369 images are now stored in ReefBase, including aerial photographs, terrestrial and underwater scenes, and low orbit NASA images.
- In addition, over 1000 images covering tropical coastal areas have now been acquired from NASA's Office of Earth Sciences.

Possible NASA Contributions

- Support an ongoing effort to populate ReefBase with satellite and aircraft imagery of the world's coral reefs.
- Develop **standard** indicators (based on satellite imagery) of reef health, productivity, and economic value.
  - ReefBase is populated with thousands of aerial photographs and Space Shuttle photos supplied by NASA/JSC. While good for term papers and press releases, these are analog images of limited value for quantitative, scientific analysis.
  - NASA could populate and maintain the database with current digital data (MODIS, Landsat, Hyperion, ALI, etc.) which would make the database much more valuable for scientific investigation.

ReefBase

Contributions details --

- The World Fish Center publishes an annual status report on the reefs of the world. Experts in each country make the evaluation, which can be highly subjective.
- An objective standard method for evaluating reef health and productivity is required to properly manage reef resources. Satellite imagery could provide the data source for such a method. NASA could work on the reef health/productivity algorithms in collaboration with coral experts.

ReefBase

Past or Current NASA Activities

- Addition of hand-held Shuttle photographs to ReefBase
- Fusion of Shuttle photography with SeaWiFS images (see publication 1)
- Benthic mapping in tropical waters using high resolution hyperspectral imagery (see publication 2)

NASA Workforce Experience

Coastal Water Quality

- **Carlos Del Castillo**, **Richard Miller**, **Callie Hall**, **Bruce Spiering** (Stennis), Coastal remote sensing applications development
- **Frank Hoge** (Wallops), Lead Investigator for Ocean Color Development and Validation
- **John Moisan** (Wallops), Lead Investigator for Coastal ocean observation, simulation, and analysis

Coral Reef Mapping and Health Assessment

- **C. Wayne Wright** (Wallops), Lead Investigator for Experimental Advanced Airborne Research LiDAR (EAARL), Seagrass and coastal habitat applications
- **Liane Guild** (Ames), Ecosystem Science and Technology Branch, Remote sensing of coral reef health

Remote Sensing of Phytoplankton Physiology and Taxonomy

- **Alexander Chekalyuk** (Wallops), Lead Investigator for Advanced Coastal Laser Biomonitoring, Phytoplankton physiological assessment using superactive-active-passive (SAP) systems

ReefBase References

- Webpage: www.reefbase.org
- Publications:
  - Robinson, J. A., G. C. Feldman, N. Kuring, B. Franz, E. Green, M. Noordeloos, and R. P. Stumpf. 2000. Data fusion in coral reef mapping: working at multiple scales with SeaWiFS and astronaut photography. Proceedings of the 6th International Conference on Remote Sensing for Marine and Coastal Environments, Vol. 2, pp. 473-483.
  - Clark, C., H. Ripley, E. Green, A. Edwards, P. Mumby. 1997. Mapping and measurement of tropical coastal environments with hyperspectral and high spatial resolution data. International Journal of Remote Sensing, 18 (2): 237-242.
  - Guild, L., "Clues to Coral Reef Health", Fall AGU, Dec 8, 2002

ReefBase

NOAA already has the operational coral product described below.

The NOAA satellite-derived Degree Heating Week (DHW) is an experimental product designed to indicate the accumulated thermal stress that coral reefs experience. A DHW is equivalent to 1 week of sea surface temperature 1 deg C above the expected summertime maximum. For example, 2 DHWs indicate 1 week of 2 deg C above the expected summertime maximum. It has been observed that DHWs of 10+ have been accompanied by severe bleaching and often mortality.

ReefBase

NOAA also supports the Coastal Reef Early Warning System (CREWS) described below.

CREWS produces automated electronic mail and World-Wide Web alerts when conditions are thought to be conducive to, or predictive of, coral bleaching. Data from remote sites are collected continuously and transmitted via satellite to Wallops Island Virginia. The analysis of this data has been automated by a near real-time rule-based expert system which produces the predictions and alerts. CREWS can be extended to monitor additional parameters and prepare alerts to other biological and natural events.

Satellite data collected (ongoing) for ReefBase could be used to enhance CREWS.

SAFESEAS
Decision Support System

"First Look" Evaluation

Coastal Management

- Federal, state, and local coastal managerslevels are responsible for
  - coastal resources planning
  - environmental compliance
  - event response
- Coastal management issues include
  - Harmful algal blooms
  - Benthic mapping
  - Community growth
  - Coastal water quality
  - Anoxia/hypoxia
  - Sea level rise
  - Coastal inundation/erosion
  - Wetland assessment
  - Coastal habitat conservation

The purpose of the Coastal Management National Application is to evaluate and benchmark NASA data, assimilation techniques, and technologies to support operational coastal decision support and coastal NSDI

SAFESEAS Facts

- Owner Agency:

NOAA, National Weather Service
Office of Science and Technology
Meteorological Development Laboratory

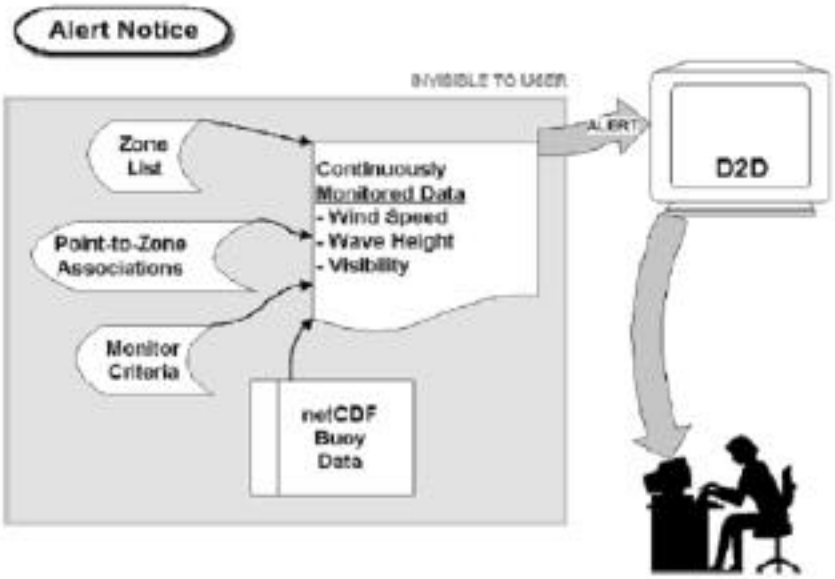
- POC:

SAFESEAS Operational Concept

- The System on AWIPS for Forecasting and Evaluation of Seas and Lakes (SAFESEAS) automatically monitors the input data stream on the NWS Advanced Weather Interactive Processing System (AWIPS) to pick out information relevant to weather threats to coastal concerns.
- Four extracted variables; wind speed, wind gust, wave height, and visibility are compared with threshold levels.
- Warnings are automatically generated when threshold are exceeded.
- The user may customize SAFESEAS by defining a local area of interest and by modifying the threshold table.
- SAFESEAS is a real-time DSS that considers only a two hour time window.

SAFESEAS

Monitoring and Alert Display



SAFESEAS

Marine Plot on D-2D Display

SAFESEAS Outputs

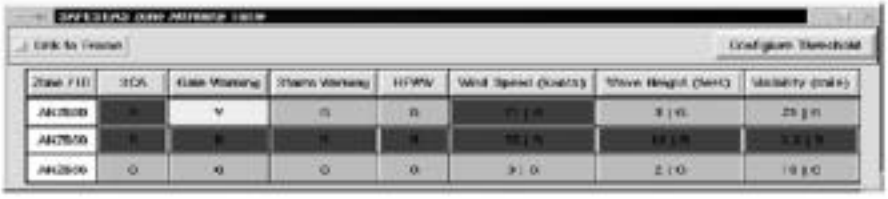
A SAFESEAS "product" corresponds to a marine watch or warning depending on the combination of variables and thresholds shown below.

- "Small craft advisory" based on wind speed, gust, and wave height
- "Gale warning" based on wind speed and gust
- "Storm warning" based on wind speed and gust
- "Hurricane force wind warning" based on wind speed and gust

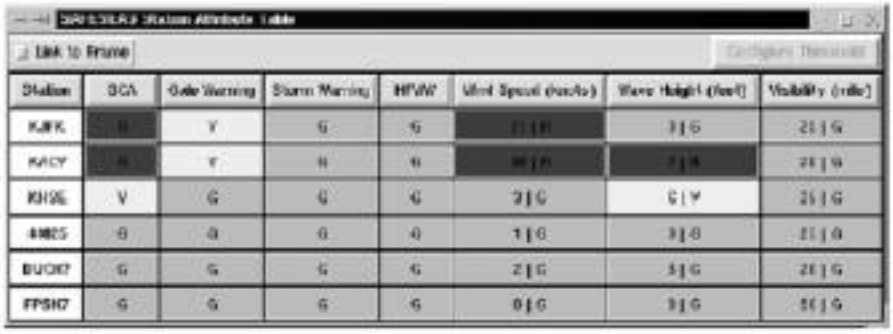
Threat levels are categorized in a "green", "yellow", "red" scheme.

SAFESEAS

Detailed Zone/Station Data Display Tables



Zone FID	SCA	Gale Warning	Storm Warning	HFWW	Wind Speed (knots)	Wave Height (feet)	Visibility (miles)
AK0509	R	Y	G	G	2 | 0	3 | G	2S | G
AK0509	R	R	R	R	2S | R	4 | R	1 | R
AK0509	G	G	G	G	2 | G	2 | G	1S | G



Station	SCA	Gale Warning	Storm Warning	HFWW	Wind Speed (knots)	Wave Height (feet)	Visibility (mile)
KJFK	R	Y	G	G	2 | G	3 | G	2S | G
KACY	R	Y	R	R	2 | R	4 | R	2S | R
KHSE	Y	G	G	G	2 | G	G | Y	2S | G
ANES	G	G	G	G	1 | G	3 | G	2S | G
BUOY	G	G	G	G	2 | G	3 | G	2S | G
FPSN7	G	G	G	G	0 | G	3 | G	3S | G

SAFESEAS Inputs

- SAFESEAS monitors
  - METARS (hourly aviation reports)
  - Buoy reports
  - Ship reports
  - Coastal-Marine Automated Network (C-MAN) reports
- And bases the threat level on four variables
  - Wind speed
  - Wind gust
  - Wave height
  - Visibility

Possible NASA Contributions

- Although satellites generate data on wind speed, wave height, and visibility the temporal and spatial sampling characteristics of these observations are not matched to this application. In addition the two hour time window to support real-time operations requires that any NASA data used be received, processed, and sent out the NOAAPort to AWIPS within one hour of overpass. NASA does not support this type of operational quick turn-around.
- There appear to be no NASA contributions here.

SAFESEAS References

•Website: www.nws.noaa.gov/mdl/safeseas/

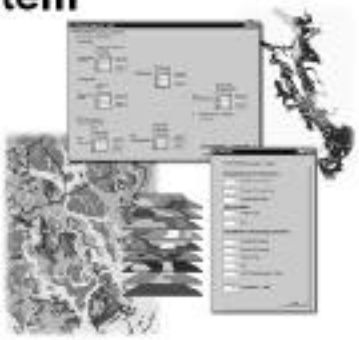
•Publication

– SAFESEAS, (*S*ystem on *A*WIPS for *F*orecasting and *E*valuation of *S*eas and Lakes), Requirements Review, Tuesday, April 16, 2002.

SWAMP
Spatial Wetland Assessment for Management and Planning

Decision Support System

First-Look Evaluation



NOAA Coastal Services Center

Coastal Management

- Federal, state, and local coastal managers levels are responsible for
  - coastal resources planning
  - environmental compliance
  - event response
- Coastal management issues include
  - Harmful algal blooms
  - Benthic mapping
  - Community growth
  - Coastal water quality
  - Anoxia/hypoxia
  - Sea level rise
  - Coastal inundation/erosion
  - Wetland assessment
  - Coastal habitat conservation

The purpose of the Coastal Management National Application is to evaluate and benchmark NASA data, assimilation techniques, and technologies to support operational coastal decision support and coastal NSDI

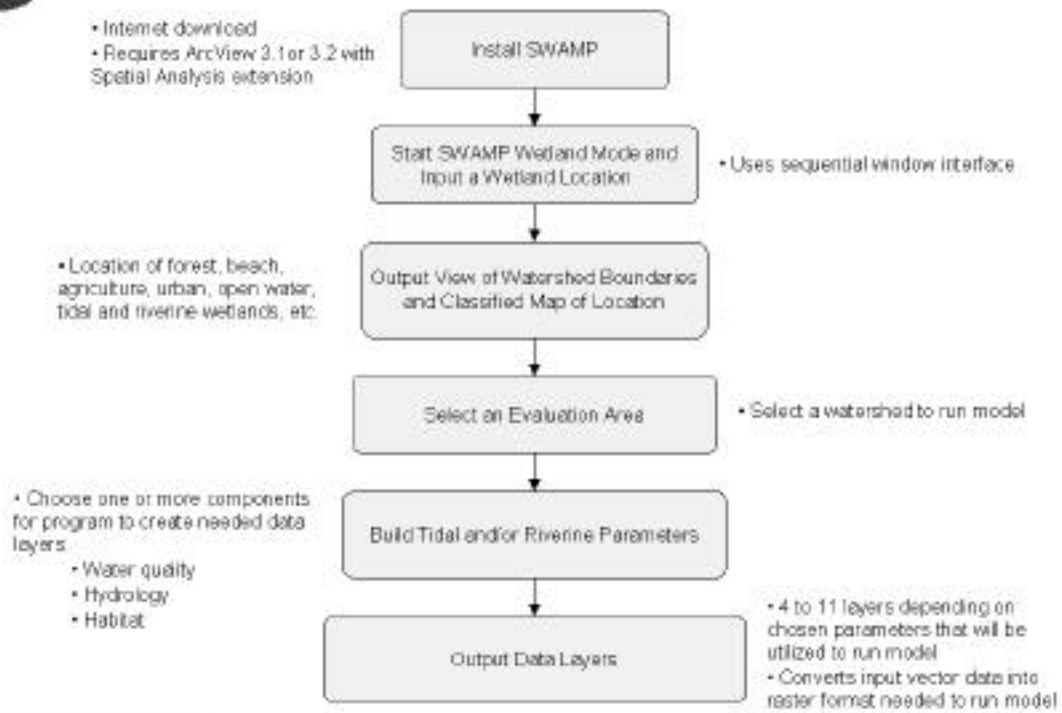
SWAMP Coastal Management

- Wetlands constitute a large portion of the natural coastal landscape and contribute to water quality, flood attenuation, estuarine productivity, and wildlife habitat
  - Wetlands continue to be drained or filled for development at a rapid rate
    - Protection and restoration of wetlands is of significant concern to coastal managers to aid land use planning and management
- Spatial Wetland Assessment for Management and Planning (SWAMP) is a Geographic Information System (GIS) rule-based model tool for examining wetland functions
  - Two modules, tidal and riverine, examine how wetlands within a watershed contribute to three wetland functions: Water quality, Hydrology, Habitat
- Uses site-specific characteristics (soil, vegetation, and land use) and descriptions and landscape characteristics (location, shape, and size) to derive parameters that apply assessment rules in a prescribed manner
  - Rules are based on published research or on a consensus of experts in the field
- After data layers describing the parameters are derived, a unique interface allows users to determine how these parameters should be combined into an overall assessment of the relative contribution that a specific wetland makes to the water quality, hydrology, and habitat functions of their watershed

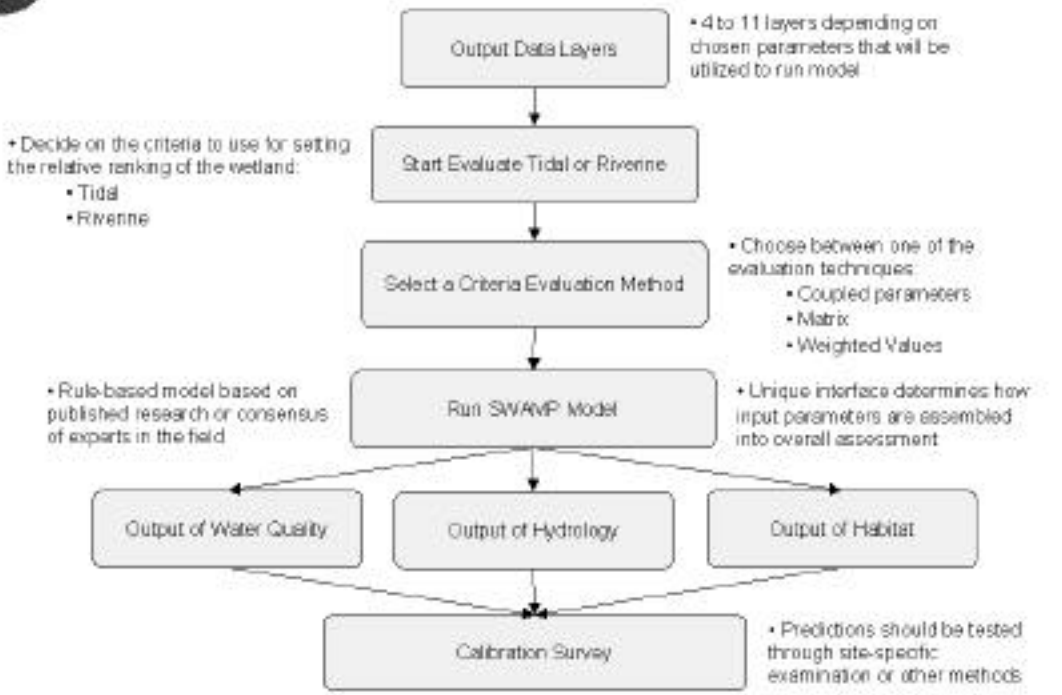
SWAMP Facts

- Developed for the Ashepoo-Combahee-Edisto (ACE) River Basin, South Carolina
  - Model is applicable to other locations provided that appropriate knowledge about the local wetland system is obtained
- Rule-based models that use a GIS to accomplish the following:
  - Organize input data
  - Allow users to customize how the parameters are combined into an overall assessment of level of function
    - Better tailor the results of SWAMP model to specific knowledge about a local wetland function
  - Run the model to apply the rules that allow the examination of wetland functions
  - Produce final products to determine the water quality, hydrology, and habitat functions in a specified watershed
    - Assessed to a rating scale
      - Exceptional
      - Substantial
      - Beneficial
      - No data

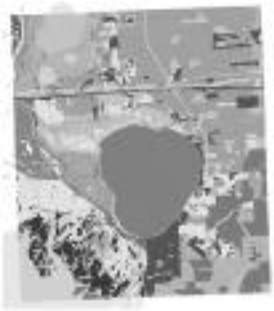
"Data Layer" Operational Concept



"Ranking" Operational Concept



SWAMP Outputs



- Map layer of watershed boundaries for a specified area
- Map layer of land use classification for a specified area
  - Examples:
    - Tidal and riverine wetland
    - Upland forest
    - Beaches/sand
    - Agriculture
    - Urban
- Output layer files to be utilized in the model
  - 4 to 11 layers depending on tidal or riverine parameters chosen; examples:
    - Riverine Water Quality
    - Tidal Habitat
- Final Water Quality, Hydrology, and Habitat GIS layer
  - Depending on specified parameter and criteria evaluation technique chosen; example:
    - Tidal Water Quality
      - Exceptional Rating
      - Substantial Rating
      - Beneficial Rating
      - No Data

SWAMP Users

- General public for educational purposes
  - Public awareness that a model exists and can be used to determine the function of water quality, hydrology, and habitat in a specified wetland environment
  - Public information concerning their local wetland habitat
- Scientific research to determine the change in the water quality, hydrology, and habitat environment when different parameters and criteria analysis techniques are run in the model
- Management and policy makers for better assessment of the ecological importance and function of wetlands to propose regulations for protection and restoration

CZM Hawaii
Coastal Zone Management

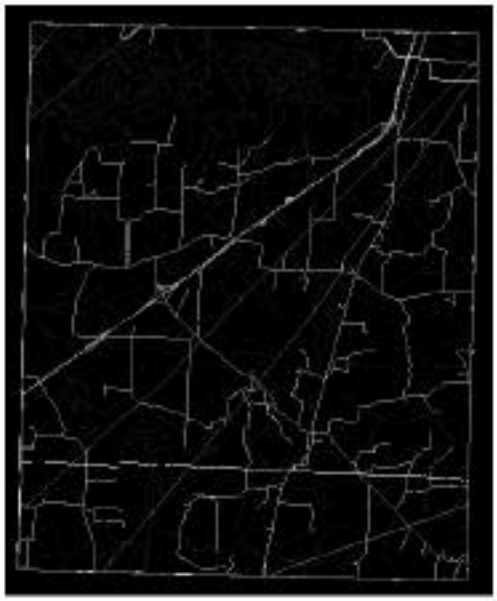
SWAMP Inputs

- Wetland boundaries and types
  - National Wetland Inventory

  - Digital data files based on wetland location and classification as defined by the U.S. Fish & Wildlife Service
  - 1:24,000 scale 7.5 minute by 7.5 minute blocks containing ground planimetric coordinates of wetlands point, line, and area features and wetlands attributes
  - Coverage for all of the contiguous United States, Hawaii, Alaska, and U.S. protectorates in the Pacific and Caribbean
- Land cover
  - NWI as described above
    - A single data layer provides both wetland boundaries and land cover classification
- Soil boundaries and types
  - 1:24,000 scale soils maps produced by the U.S. Department of Agriculture's National Resource Conservation Service (NRCS)
    - Properties of the soil are used to determine the capacity of a particular wetland function
- Hydrography
  - 1:24,000 scale U.S. Geological Survey (USGS) digital line graphs (DLGs) converted to ArcInfo coverage
    - Stream order attributes required by SWAMP are developed from 1:100,000 RF3 files produced by the Environmental Protection Agency

SWAMP Input

- Watershed boundaries
  - State-defined watershed boundaries are based on USGS 1:24,000 scale base data
- Roads
  - 1:24,000 scale USGS DLGs



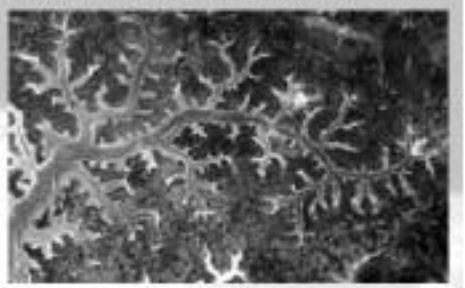
DLG depicting hydrography and roads

Possible NASA Contributions

- NASA imagery to update current National Inventory Maps used to determine wetland boundaries and land cover types and DLGs used to determine new road construction
  - Can be used to update land cover type and road layers due to rapidly changing landscapes caused by agricultural expansion, urban sprawling, industrial development, timber harvesting, and new road construction
  - Can be used to increase the accuracy of SWAMP model in predicting the importance of the wetland to the watershed
    - SWAMP relies heavily on the spatial and temporal dynamics of the wetlands
    - Majority of the parameters are derived from the landscape that represent the location, calculated distances, size, shape, and land cover type

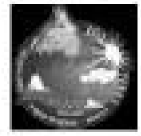
Possible NASA Satellite Imagery

- Landsat 7 orthorectified ETM imagery in geotiff format to update current classification maps and road layer; Benefits:
  - Format recognizable in most image processing software applications
  - Moderate spatial resolution will reduce number of images to mosaic (if needed) to cover desired wetland area compared to high-resolution imagery
    - Panchromatic with 15-meter spatial resolution
    - Visible, near-infrared, and short-wave infrared with 30-meter spatial resolution
    - Thermal with 60-meter spatial resolution
  - 15-meter panchromatic resolution for recognition of the surrounding environment for accurate classification methods
    - Visible and infrared can be sharpened to 15-meter spatial resolution by using panchromatic as high-resolution image for possible increased interpretability
  - 16-day temporal resolution



Possible NASA Satellite Imagery

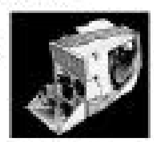
- EOS ASTER orthorectified, 15-band imagery to update current classification maps and road layer; Benefits:
  - Moderate spatial resolution will reduced number of images to mosaic (if needed) to cover desired wetland area compared to high-resolution imagery
    - Visible/Near Infrared with 15-meter spatial resolution
    - Short-wave Infrared with 30-meter spatial resolution
    - Thermal with 90-meter spatial resolution
  - 15-meter visible/near-infrared resolution for recognition of the surrounding environment for accurate classification algorithms
  - 16-day temporal resolution



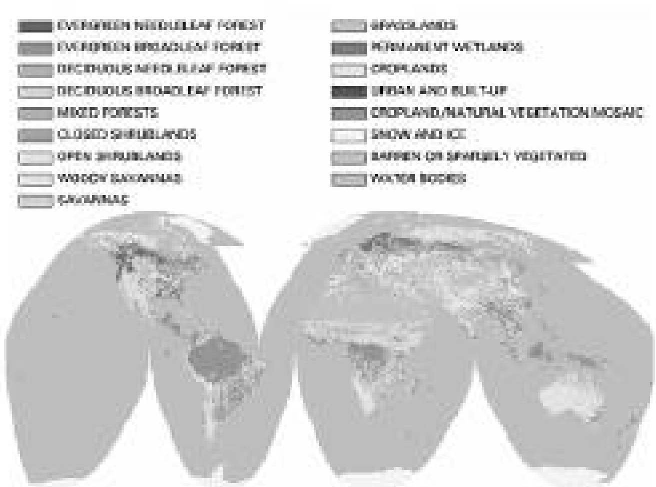
Terra Satellite

Possible NASA Satellite Imagery

- EOS MODIS Land Cover/Land Cover Change product to update current classification maps; Benefits:
  - 1 kilometer resolution that identifies 17 categories of land cover types according to the IGBP vegetation classification scheme
    - 11 classes of natural vegetation
    - 3 classes of developed land
    - 3 classes of nonvegetated land
  - Produced 4 times a year



MODIS Senor



SWAMP References

- Web sites

  http://www.csc.noaa.gov/lcr/text/swamp.html

  http://cgia.cgia.state.nc.us/cgdb/nwi.html

  http://edc.usgs.gov/products/map/dlg.html#samples

  http://ls7pm3.gsfc.nasa.gov/mainpage.html

  http://asterweb.jpl.nasa.gov/

  http://modis.gsfc.nasa.gov/data/atbd/atbd_mod12.pdf

- Publication

  List of literature cited is included in SWAMP Technical Report at
  http://www.csc.noaa.gov/lcr/images/TechDisc.pdf pp. 35 - 43

- Contact Person

  Lori Sutter
  Technology Planning and Management Corporation
  NOAA Coastal Services Center
  2234 South Hobson Avenue
  Charleston, SC 29405

WATERSHEDSS
Decision Support System

"First Look" Evaluation

North Carolina State University
Water Quality Group

Coastal Management

- Federal, state, and local coastal managerslevels are responsible for
  - coastal resources planning
  - environmental compliance
  - event response
- Coastal management issues include
  - Harmful algal blooms
  - Benthic mapping
  - Community growth
  - Coastal water quality
  - Anoxia/hypoxia
  - Sea level rise
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  - Wetland assessment
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WATERSHEDSS Basic Facts

- **WATERSHEDSS** – **WATER**, **S**oil, and **H**ydro-**E**nvironmental **D**ecision **S**upport **S**ystem
- **Owner Agency**: North Carolina State University Water Quality Group
- Developed through a grant from the USEPA, Office of Research and Development, National Exposure Research Laboratory, Ecosystems Research Division, Athens, GA. The Agricultural and Biological Engineering Department at Pennsylvania State University collaborated on the project.
- **Objectives**:
  1. Transfer water quality and land treatment information to watershed managers in order to assist them in making appropriate land management and land treatment decisions to achieve water quality goals.
  2. Assess and evaluate sources, impacts, and potential management options for control of non-point source pollution in a watershed based on user-supplied information and decisions.
- **Consists of 3 components**:
  1. Watershed Assessment and Evaluation – includes a pollutant budget spreadsheet and an agricultural best management practice (BMP) database
  2. Educational Component – contains detailed information and references on NPS pollutants and sources
  3. Annotated Bibliography of non-point source literature

WATERSHEDSS Operational Concept

- **Watershed Assessment & Evaluation**
  - Utilizes a hypertext expert-system like interface
  - User is asked a series of questions:
    - Type of water resource and use
    - Type of impairment
    - Source of pollutant
    - Regional agricultural practices
  - Based on the answers to the questions, alternative land treatment practices will be suggested
  - User interactively selects from the recommended best management practices
  - Water quality standards were obtained from various federal, state, and professional sources
  - Only one water resource, use, and impairment can be selected for each run
- **Educational**
  - Comprised of hypertext units on water quality, water quality monitoring, land treatment, watershed management, and watershed project.
- **Annotated Bibliography**
  - A link to the NCSU Water Quality Group NPS Library of literature that is searchable by author, title, keyword, or topic

WATERSHEDSS Outputs

- Watershed Assessment & Evaluation
  - Text based best management practice for selected water resource, use, and impairment
- Educational Component
  - Text information on selected topic
- Annotated Bibliography
  - Bibliography and abstract (if available) for articles that match search criteria

WATERSHEDSS Users

- Specific users are unknown
- Potential users include
  - Watershed managers
  - Land treatment personnel

WATERSHEDSS Inputs

- Watershed Assessment & Analysis
  - User selects desired water resource, use, and pollutant
  - Acreage for selected land use categories

Possible NASA Contributions

- No real potential for NASA contributions without significant changes to the DSS

WATERSHEDSS References

- Website(s): http://www.water.ncsu.edu/watershedss/
- Publication(s):

Osmond, D.L., D.E. Line, R.W. Gannon, J.A. Gale, J. Spooner, S.W. Coffey, K.A. Bartenhagen, J.C. Walker, M.A. Foster, P.D. Robillard, and D.W. Lehning. 1995. WATERSHEDSS: The Integration and Use of Wetlands and Riparian Areas in a Decision Support System. Pages 127-138 In: K.L. Campbell (ed.), Versatility of Wetlands in the Agricultural Landscape, Proceedings. Sept. 17-20, 1995, Tampa, FL. Amer. Soc. Agric. Engineers, St. Joseph, MI.

Osmond, D.L., R.W. Gannon, J.A. Gale, D.E. Line, C.B. Knott, K.A. Phillips, M.H. Turner, M.A. Foster, and D.E. Lehning. 1997. WATERSHEDSS: A Decision Support System for Watershed-Scale Nonpoint Source Water Quality Problems. *J. of the Amer. Water Resour. Assoc.*, 33(2):327-341.

- POC:

Deanna L. Osmond
Department of Soil Science
Box 7619
North Carolina State University
Raleigh, NC 27695-7619
(919) 515-7303